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2006

**NASA Range Safety
Annual Report**

**This 2006 Range Safety Annual Report
is produced by virtue of
funding and support from the following:**

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Introduction

Welcome to the 2006 edition of the NASA Range Safety Annual Report. This report, funded by NASA Headquarters, provides a NASA Range Safety overview for current and potential range users. This year we present summaries from the various NASA Range Safety Program activities that took place throughout the year, as well as information on several special projects that appear to have a profound impact on the way we will do business in the future.

The sections include development of range safety policy (especially with regard to the Constellation Program), NASA Range Safety non-compliance procedures, risk assessment activities, an overview of NASA Range Safety Training, independent assessment updates, our involvement with the Common Standards Working Group, updates to existing range safety policy and guidance, new and interesting developments in the range safety systems realm, our involvement with uninhabited aerial vehicle requirements development, NASA Range Safety support to launch programs, and reports from our various Centers.

As is the case each year, contributors to this report are too numerous to mention, but we thank individuals from the NASA Centers, the Department of Defense, and civilian organizations for their contributions. We've made a great effort to include the most current information available. We recommend the report be used only for guidance and the validity and accuracy of all articles be verified for any updates since this writing.

This is the last year I will oversee the production of this report. As of December 2006, Mr. Alan Dumont assumed duties as the Agency Range Safety Manager. Alan's most recent role was Kennedy Space Center Range Safety Manager, and he possesses significant experience in the range safety arena. He's worked as a Mission Flight Control Officer at both the Eastern and Western Ranges and also was Chief of Flight Analysis at the Eastern Range before joining NASA in 2004. The future is bright with Alan on board!

You'll note we've transitioned to a web-based format this year. We hope you'll find this very useful, as we've provided links to numerous references and graphical aids. We'd like to especially thank Mr. Tony Anderson from NASA-KSC for his expertise and professionalism in the creation of this web based product. Enjoy!

Maria A. Collura, NASA
Outgoing Range Safety Manager



Agency Range Safety Program

Program Overview and 2006 Highlights

2006 proved to be another eventful and exciting year in the Range Safety realm. Before we highlight the areas covered in this year's edition, it's important to restate the goal of the NASA Range Safety Program. The program is defined in NPR 8715.5, dated 8 July 2005, and is signed by the NASA Administrator. The goal of the program is to protect the public, the workforce, and property during range operations such as launching, flying, landing, and testing launch vehicles. This goal applies to all centers and test facilities and all space vehicle programs including expendable launch vehicles, reusable launch vehicles, uninhabited aerial vehicles, and the Space Shuttle as well as any NASA-funded commercial ventures that involve range operations. We meet the goal of the NPR by mitigating and controlling hazards, such as uncontrolled vehicles, debris, explosives, and toxics associated with range operations.

In this issue, we cover several areas of range safety that point to how we meet or implement the range safety program. One of our primary focuses relates to range safety training and our continuing efforts regarding the NASA Range Safety Training Program. We brought one additional class on-line in 2006, and are poised to bring another course on-line in 2007. We've also been extremely busy in the development, implementation, and support of range safety policy.

The year started out in full swing with the advent of the Constellation Program. Since last December, we've been working the challenges associated with bringing a new program to Kennedy Space Center. We also cover the strides we've made regarding the risk and variance processes that are now in place for flights from the Eastern and Western Ranges. We're also busy working on agreements with the Eastern and Western Ranges regarding NASA Range Safety on-console launch support. In 2005, we secured agreements with the ranges regarding personnel on-console for NASA launch operations. In 2006, we worked to further codify these processes.

NASA Range Safety personnel continue to support the Range Commander's Council meetings and have been involved in updating policy related to flight safety systems and flight safety analysis. A recap of these efforts is highlighted. We address our continued support to the Common Standards Working Group in updates to current range safety policy, as well as assisting in development of new policy for reusable launch vehicles. We are also working with the 45th Space Wing Safety Office to develop a policy document for unmanned aerial vehicles that we hope to use to promote safe flying at Kennedy Space Center and on the Eastern Range in the not-too-distant future.

Another milestone achieved this year was gaining approval of the Space Shuttle Launch and Landing Implementation Plans. NASA Range Safety also stayed fully engaged on issues related to flight safety systems throughout the year. A detailed discussion of the challenges the range safety community is currently facing regarding flight safety systems in the areas of secure technology and frequency use is provided.

In addition to working training and policy issues, NASA Range Safety was involved in one independent assessment of Orbital Sciences Corporation in 2006. We also present our efforts in establishing or identifying a common risk analysis tool for use at all NASA launch locations. This issue focuses on our efforts to properly account for personnel on center during launch operations via the Self-Service Management Tool that is in use at

Kennedy Space Center. We address launch operations at other NASA Centers, specifically with support provided to Wallops Flight Facility for the launch of TACSAT-2 on a Minotaur launch vehicle, and we provide a re-cap of launches from all ranges for the year.

One of the areas that holds the interest of many in the range safety community is emerging range safety technology. Articles that focus on space based range capabilities, autonomous flight safety systems, the enhanced flight termination system, the joint advanced range safety system and the subminiature flight safety system are included in this issue. In addition, we cover instrumentation upgrades that have been put in place at the Eastern Range over the year.

This issue provides insight into some special interest items, specifically the details surrounding distant focusing overpressure modeling and how that relates to launch risk. Other articles address on the State of Florida's efforts to educate launch providers on range safety and recent strides in the expendable launch vehicle payload safety world.

We wrap this issue up with range safety reports from the NASA Centers that were actively involved with range safety issues throughout the year. The graphic below gives a brief overview of the major topics contained in this report. Feel free to migrate directly to any topic by selecting items that are of interest.

(Tony...can we provide links from this graphic?)



NASA Range Safety Training 2006

The NASA Range Safety Training program remained a primary focus of NASA Range Safety once again this year. This effort began in 2002 and covers all topics of range safety in detail. These programs address the training needs for range safety personnel and are applicable and available to NASA, the Department of Defense, the Federal Aviation Administration, and the Missile Defense Agency. Final development of all training is almost complete. The final phase of training, the *Range Safety Operations* course, is anticipated to come on-line in 2007. The graphic below illustrates the two-phase development process we used for these courses.

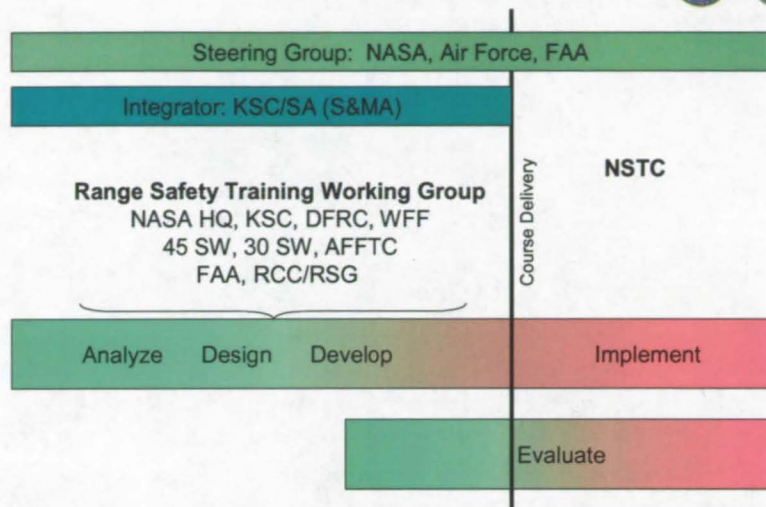


The development strategy originally put in place has served well in reaching critical milestones to date. An original steering group comprised of NASA, the Air Force, and the Federal Aviation Administration provided the foundation for the basic outlines of the courses.

Depending on the course content, the Range Safety Training Group had representatives from NASA Head Quarters, Kennedy Space Center, Dryden Flight Research Center, Wallops Flight Facility, 45th and 30th Space Wings, the Air Force Flight Test Center, the Federal Aviation Administration, the Missile Defense Agency, and members of the Range Commanders Council/Range Safety Group.

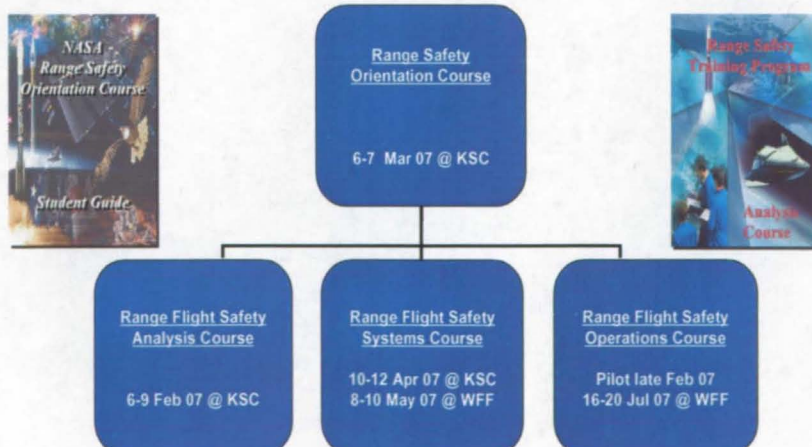
These parties were charged with analyzing, designing, and developing the individual course content, leading to delivery at the NASA Safety Training Center. The training center provides implementation and evaluation of the training. This development strategy is shown below.

Development Strategy



To date, we've conducted fifteen *Range Safety Orientation* courses with 415 students in attendance, three *Flight Safety Analysis* courses with 45 students in attendance, and one *Flight Safety Systems* course with 15 students. The *Range Safety Operations* course is progressing well, and we anticipate the first course will take place at Wallops Flight Facility in July of 2007. The graphic below shows the schedule for all courses for 2007.

2007 Classes



Range Safety Orientation

The *Range Safety Orientation* course is designed to give NASA senior, program, and project managers an understanding of the Range Safety mission, associated policies and requirements, and NASA roles and responsibilities. It introduces the major ranges and their capabilities, defines and discusses the major elements of Range Safety (flight analysis, flight termination systems, range operations), and briefly addresses associated range safety topics such as ground safety, frequency management, and uninhabited aerial vehicles.

The course emphasizes the principles of safety risk management to ensure the public and NASA workforces are not subjected to risk of injury greater than their normal day-to-day activities. It is designed to inform the audience of the services offered by the Range Safety organization and to recommend ways of making the working relationship with Range Safety most beneficial for the Range User. It also presents timeframes that allow adequate interface with Range Safety during program/project startup and design to minimize potential delays and costs. This course includes a visit to range safety facilities at Cape Canaveral Air Force Station and Kennedy Space Center and will normally only be given at this location. If you wish to discuss presenting the class at your location, please contact the NASA Safety Training Center staff.

Target Audience: Senior, program, and project managers; Safety, Reliability, Quality, and Maintainability professionals with an interest in range safety activities

The *Range Safety Orientation* course includes the following topics:

- Range Safety Mission and Organization
- Policies, Standards, and Directives
- Launch and Test Facilities
- Flight Analysis
- Flight Termination Systems
- Tracking and Telemetry Systems
- Range Safety Operations
- Ground Safety
- Frequency Management
- Uninhabited Aerial Vehicles
- The Way Ahead
- Hands-On Orientation



Range Flight Safety Analysis

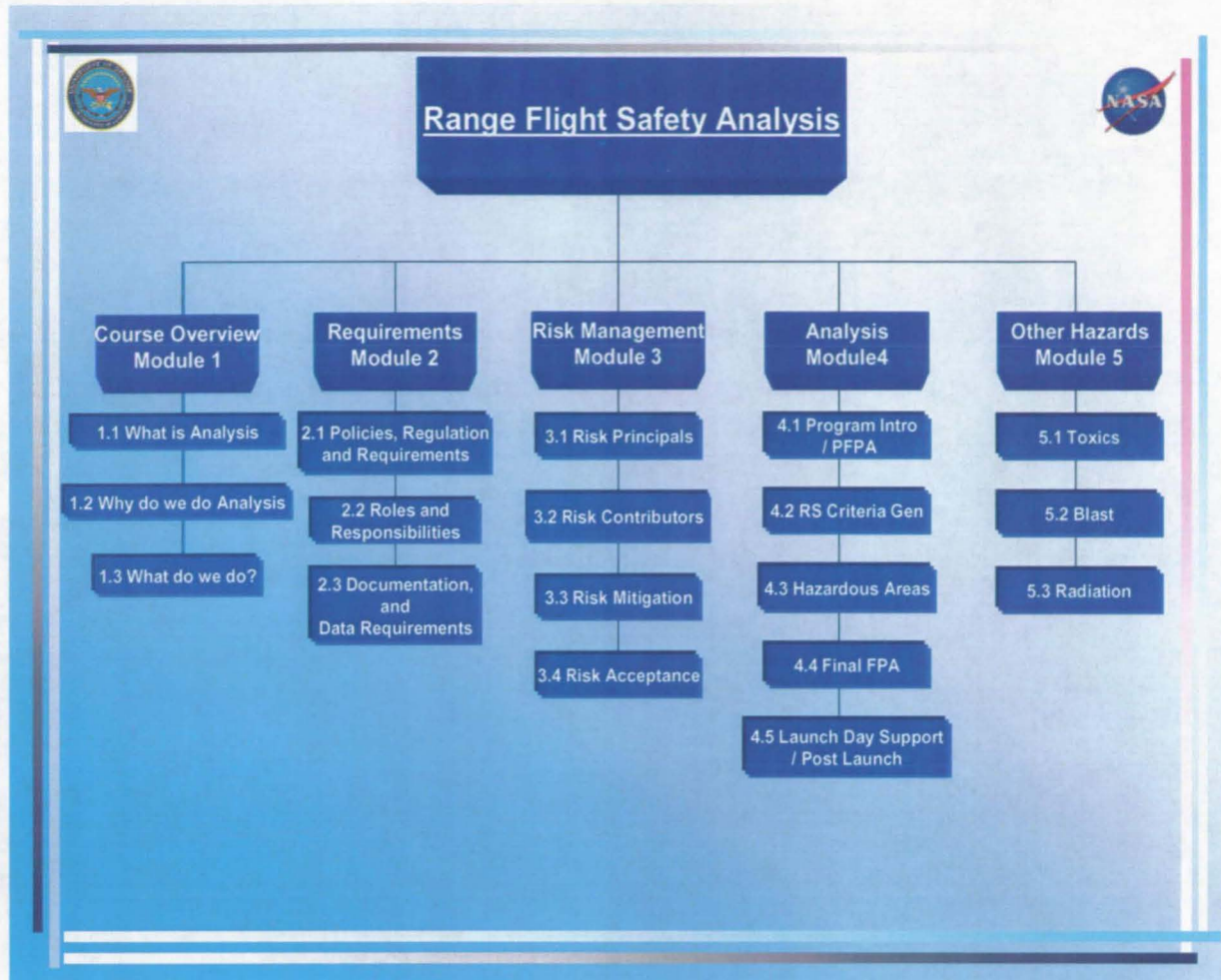
The *Range Flight Safety Analysis* course provides a detailed understanding of range safety analysis. It includes NASA, Federal Aviation Administration, and Department of Defense requirements for flight safety analysis; a discussion of range operations hazards, risk criteria and risk management processes; and an in-depth coverage of the containment and risk management analyses performed for expendable launch vehicles at the Eastern Range.

Although the course is based on expendable launch vehicles at the Eastern Range, the overall analysis process and concepts are applicable to other vehicles and other ranges as well. The course concentrates on debris hazards and analyses but includes an overview of toxic, blast, and radiation analyses. The course includes a class exercise that covers the entire analysis process.

Prerequisite: Completion of NSTC 074, *Range Safety Orientation*, or equivalent experience (engineering degree and a background in range safety).

Target Audience: NASA, Federal Aviation Administration and Department of Defense Range Safety Analysts; range safety personnel in other disciplines; program/project managers and engineers who design potentially hazardous systems to operate on a range

The *Range Flight Safety Analysis* course outline is shown in the graphic below.



Range Flight Safety Systems

The second of three Phase II courses, *Range Flight Safety Systems*, was taught for the first time at Kennedy Space Center in September of 2007 with 15 students in attendance. The course size is limited by tours conducted at the Navy Trident trainer facility. The course describes required safety responsibilities and flight termination system procedures and plans. It also includes flight termination system component design, performance, test, and subsystem pre-launch requirements.

The module then transitions to the applicable flight termination system ground support and monitoring equipment, flight termination system analysis, and component test history. The course continues with a review of uninhabited aerial vehicle flight termination systems, balloon universal termination packages, and the enhanced flight termination system. The class concludes with a description of the autonomous flight safety system.

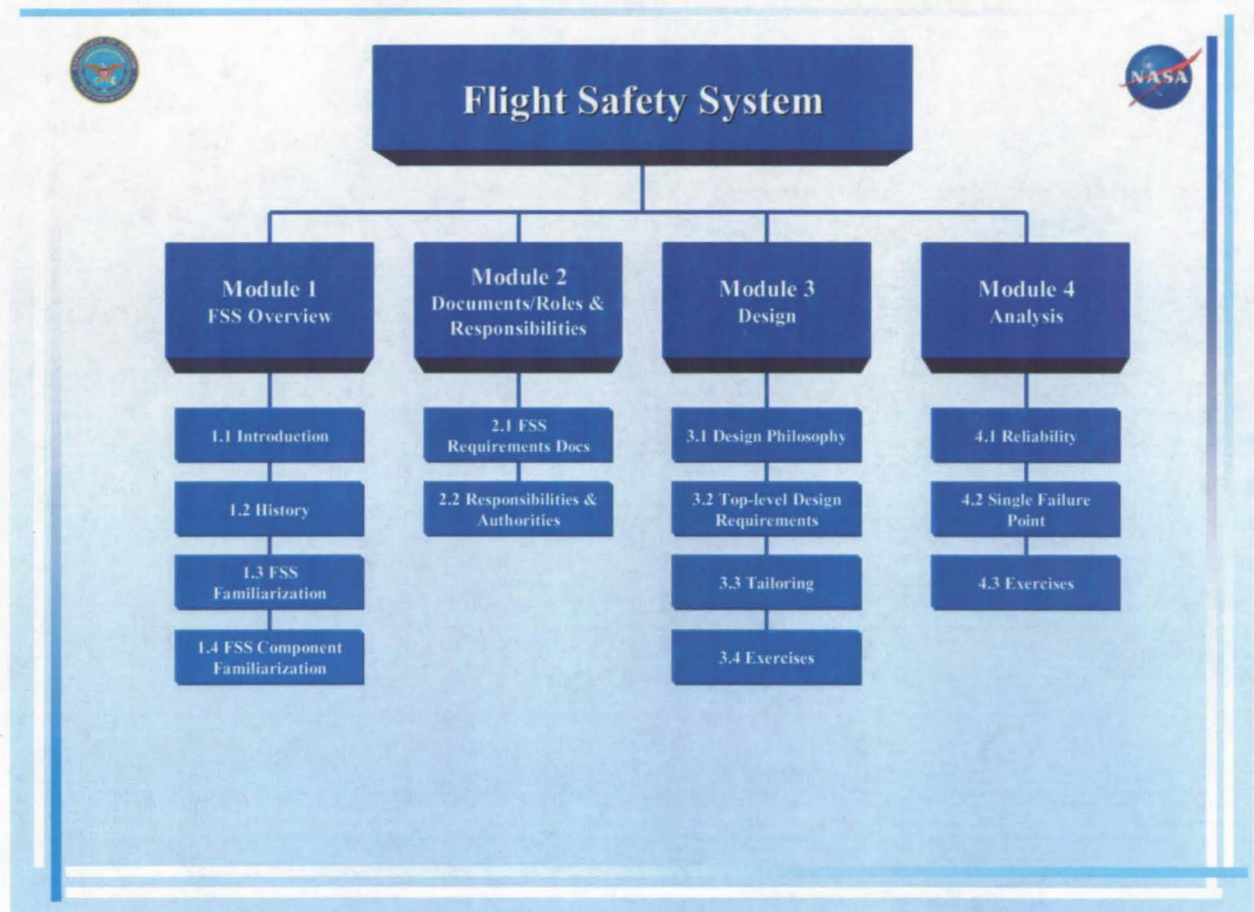
Prerequisites:

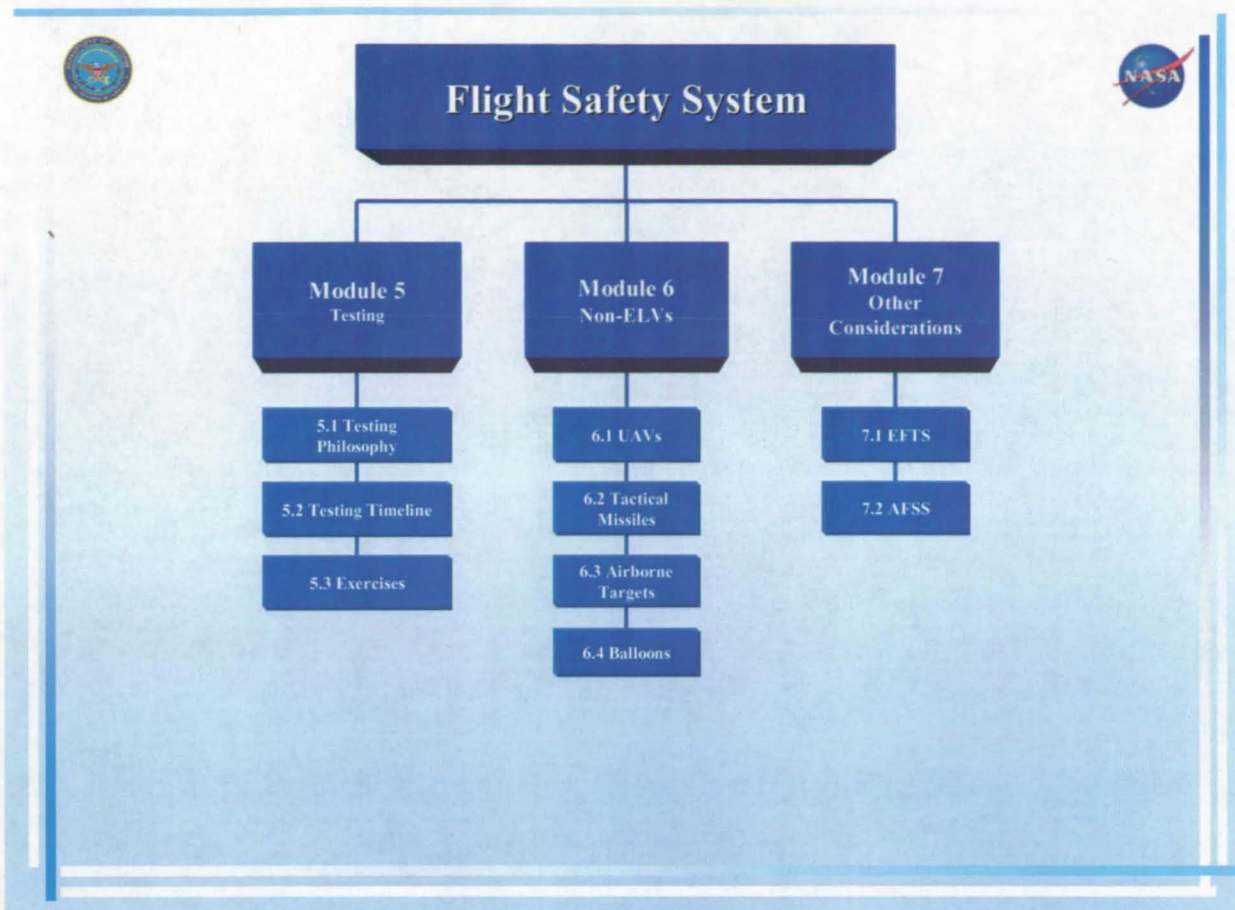
Completion of NSTC 074, *Range Safety Orientation*, or equivalent level of experience or training, is required

Completion of NSTC 002, *System Safety Fundamentals*, or NSTC 008, *System Safety Workshop*, is recommended

Target Audience: NASA, Federal Aviation Administration, and Department of Defense Range Safety personnel working flight safety systems issues; range safety personnel in other disciplines; program/project managers and engineers who design potentially hazardous systems to operate on a range; personnel who conduct hazardous operations on a range

The *Range Flight Safety Systems* course outline is shown in the two graphics below.





Range Safety Operations Course

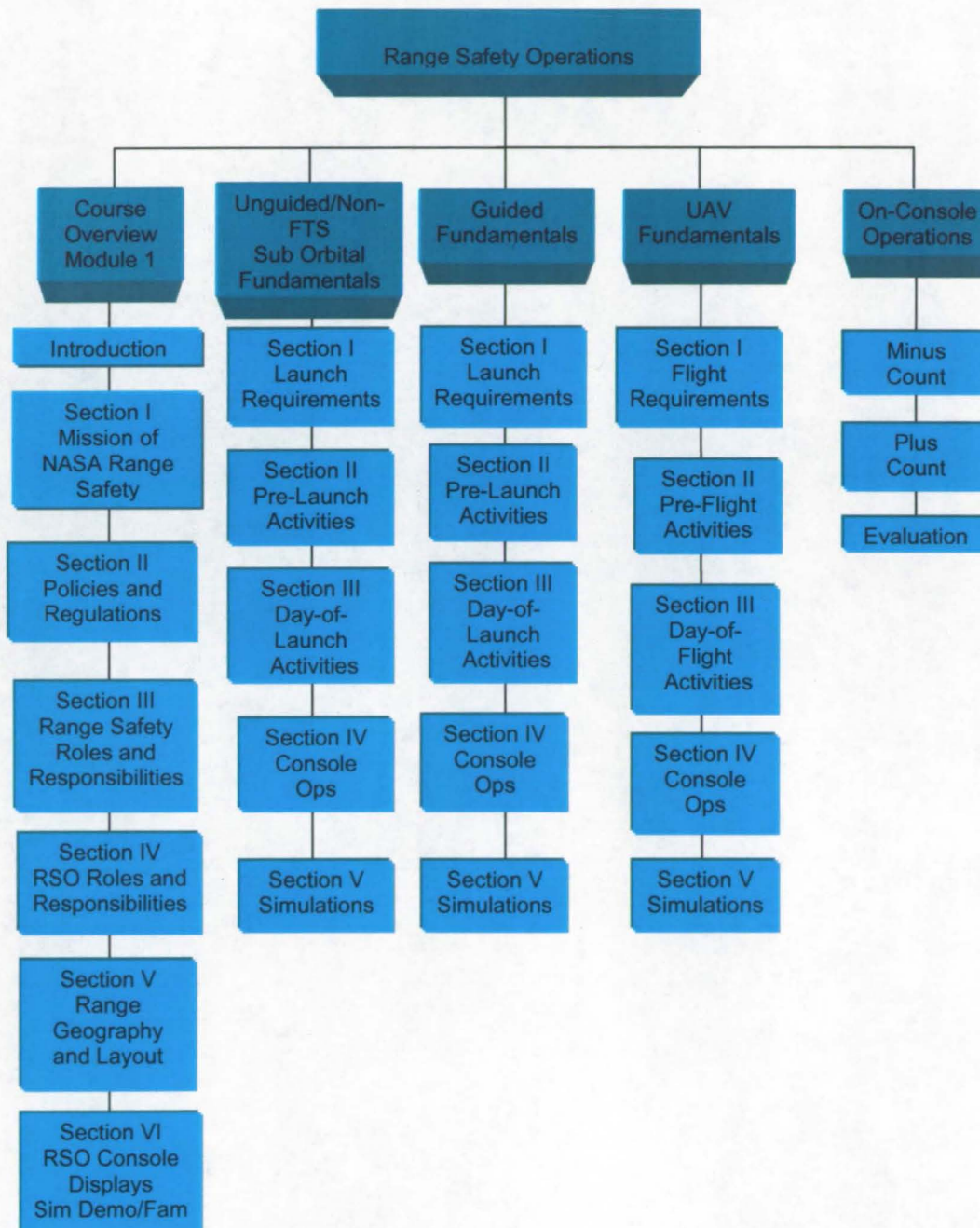
Development of the *Range Safety Operations* course, the last of three Phase II advanced courses, should be completed in early 2007 and will be offered for the first time in July 2007. The course is managed by the NASA Safety Training Center and taught by several range safety operations professionals from NASA and other federal agencies involved in range safety. Unlike previous courses, this course will be taught at Wallops Flight Facility to take advantage of its range safety and control room facilities, as well as the mobile range safety system assets.

To ensure mission success and the safety of operations for the range, a formal process has evolved among the different ranges to provide range safety operations. This course focuses on the roles and responsibilities of the Range Safety Officer for range safety operations, as well as real-time support, including pre-launch, launch, flight, landing, and required mitigation actions. Launch commit criteria, mission rules, countdown activities, and display techniques are presented.

Additionally, tracking and telemetry, along with vehicle characteristics and range generation and checkout, will be covered in detail. Finally, post operations, lessons learned, and the use and importance of contingency plans will be discussed. Those

participating in the course receive hands-on simulator training and exercises to reinforce range safety officer techniques and procedures to successfully conduct launch operations. Due to the unique interaction with real-world equipment, a maximum of six students may attend each class. Current forecasts are to offer this course annually; however more classes may be added based on need.

The course design document was completed in 2005. The course centers on the topics shown in the graphic below.



If you wish to take of any of the courses offered, please contact your Center training manager or refer to the NSTC web site course catalogue located at:
http://www6.jsc.nasa.gov/safety/calendar/NSTC/Docs/2007_Catalog.doc

Development, Implementation, Support of Range Safety Policy

Constellation

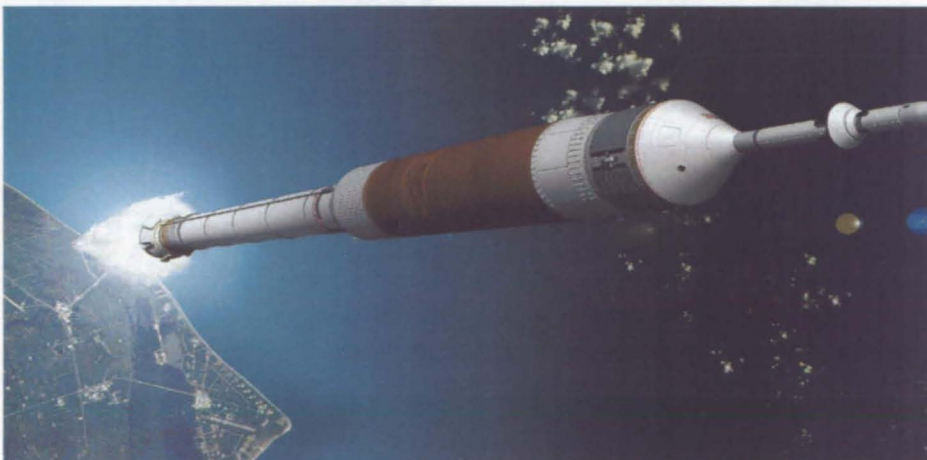
Constellation is the combination of large and small systems that will provide humans the capabilities necessary to travel and explore the solar system. Constellation will be made up of Earth-to-orbit, in-space and surface transportation systems, surface and space-based infrastructures, power generation, communications systems, maintenance and science instrumentation, and robotic investigators and assistants

In 2006, NASA named the new rockets that will carry the next generation of space explorers to the moon and beyond. *Ares*, the Greek god associated with the planet Mars, is a fitting title for NASA's new wave of exploration vehicles by that will one day carry explorers to Mars. The new crew exploration vehicle that will carry astronauts to the Moon, the International Space Station, and eventually to Mars was also named in 2006. This vehicle is called *Orion* after one of the brightest most recognizable star formations in the universe. By 2020, NASA astronauts will once again walk on the surface of the moon and prepare for their eventual journey to the planet Mars.

Ares I

Ares I is the vehicle that will send the next generation of explorers into space. Also known as the crew launch vehicle, this is a single, two-stage rocket derived from the Space Shuttle's solid rocket booster. The first stage is a reusable, five-segment, solid rocket booster much like the four-segment booster the Shuttle uses today. The solid rocket booster will power the rocket to approximately 200,000 feet where the first stage will separate and allow the second stage engine take over. The Ares I rocket is also capable of lifting more than 55,000 pounds into low Earth orbit. The prime contract for the first stage belongs to ATK Thiokol of Brigham City, Utah.

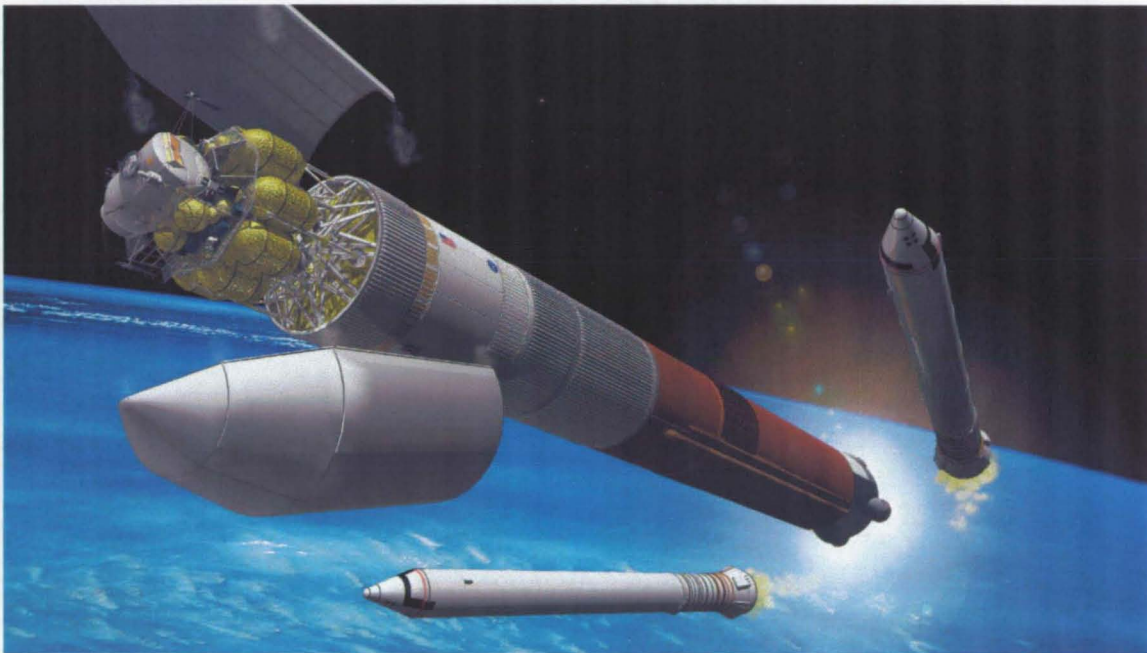
The second stage engine is a liquid oxygen/liquid hydrogen fueled J-2X, similar to the engine used on the second stage of the Apollo rocket. Sitting atop the five-segment booster is the Orion crew exploration vehicle. This capsule will be the short-term home for astronauts launched from Kennedy Space Center and will ferry crews to and from the Moon and the International Space Station. Pratt and Whitney Rocketdyne in Canoga Park, California is the prime contractor for the engine of the second stage.



Ares V

The [Ares V](#), also known as the cargo launch vehicle, is 360 feet tall and capable of lifting more than 286,000 pounds to low Earth orbit. This lift is achieved by using two five-segment solid rocket boosters mounted on either side of a similar, but larger version of the Shuttle's external tank that is powered by five, RS-68, liquid oxygen/liquid hydrogen engines. This vehicle will be used to carry cargo and other equipment into orbit with a final destination of the Moon or even Mars.

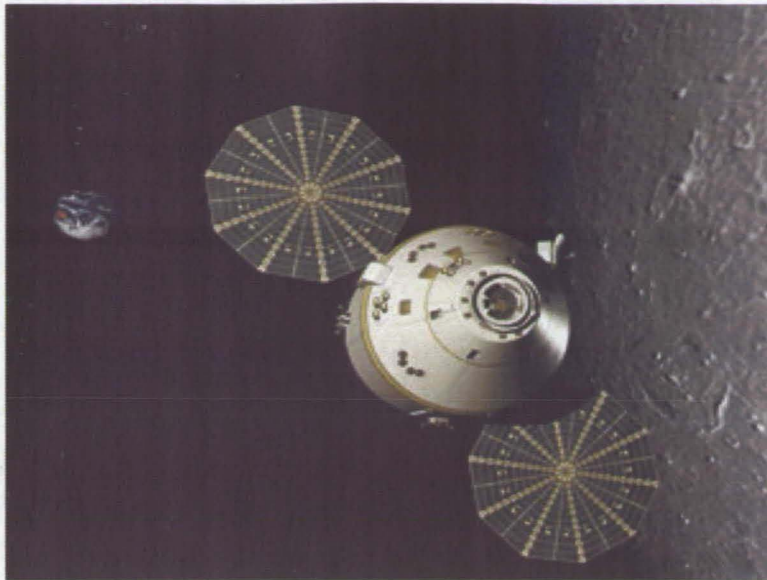
The first stage and core stage will power the vehicle toward orbit until it is time for separation from the upper stage. This upper stage, known as the earth departure stage, is powered by a J-2X engine and is responsible for putting the vehicle into a circular orbit. Once this orbit is achieved, the Orion crew exploration vehicle will dock with the earth departure stage and begin its journey to the Moon and beyond.



Orion Crew Exploration Vehicle

The [Orion](#) crew exploration vehicle will carry astronauts to and from the Moon, Mars, and the International Space Station. The capsule is designed in a similar fashion to that of the Apollo capsule of the past except this time it will be roughly three times larger. The vehicle is designed to be aerodynamically stable for nominal entries as well as emergency aborts.

This version of the crew exploration vehicle will have modern materials and manufacturing processes, advanced avionics, improved operational capability, and the ability to land on ground rather than water. The crew exploration vehicle rests atop the Ares I rocket and will be capable of docking with the International Space Station as well as the earth departure stage of the Ares V cargo launch vehicle. The primary contract to design and build Orion was awarded to the Lockheed Martin Corporation of Bethesda, Maryland in September 2006.



Lunar Surface Access Module

The [lunar surface access module](#) will carry astronauts to and from the surface of the Moon. It is launched into orbit within the Ares V configuration. A composite shroud or fairing protects the module when it sits atop the earth departure stage during launch. The Orion crew exploration vehicle will mate with the earth departure stage and lunar surface access module and move towards lunar orbit. Once this orbit is achieved, the astronauts will migrate to the lunar module and make their way to the moon's surface. The Orion vehicle will remain in lunar orbit while the lunar module descends towards the surface of the moon.

The lunar module is very similar to the lunar vehicle used for the Apollo missions, except this module is larger, with the capability of carrying four astronauts, and has the ability to land almost anywhere on the Moon's surface. When it is time for the astronauts to leave the Moon's surface, the lunar vessel will depart from the lunar surface access module and carry them back to Orion where they will make their final trip home.



Range Safety Challenges

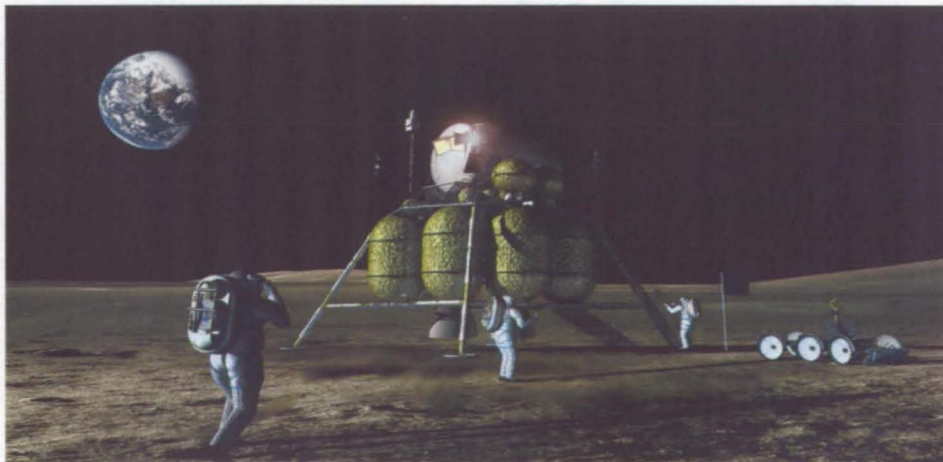
As with all previous launches and programs, safety will continue to be an important issue to the Constellation Program and Range Safety. Not only is it important that these vehicles succeed in reaching areas of the universe that were once believed unreachable, but it is equally important to protect the public, the astronauts, and the workforce that make these dreams possible.

As we headed into 2006, we were already assisting the Constellation Program in defining range safety related requirements. This effort began with a complete review of the NASA Range Safety [NPR 8715.5](#) to identify areas applicable to the program. The review was followed by the establishment of the Launch Constellation Range Safety Panel, co-chaired by Johnson Space Center/Flight Design and Dynamics Division and the 45th Space Wing Safety Office with NASA Range Safety and many other NASA and Air Force personnel as members. After panel members were determined, an initial technical interchange meeting was held at Kennedy Space Center in early 2006.

Several questions still remain unanswered about the future of the Constellation program. Some of the most important issues related to Range Safety are as follows:

- Will the flight termination system include a linear shape charge extension to cover the aft segment of the solid rocket boosters for the test flights?
- What type of ascent and reentry requirements will be implemented?
- At what frequency will the flight termination system operate?
- Will the Constellation program implement any new technologies pertaining to the flight termination system, such as the enhanced flight termination system?
- What type of tracking and communications requirements will be implemented?

These are just a few of the important questions that must be answered by Range Safety to ensure public safety. The Constellation Program and Range Safety are committed to making the Constellation family of vehicles the safest and most reliable launch vehicles ever to launch from Kennedy Space Center.

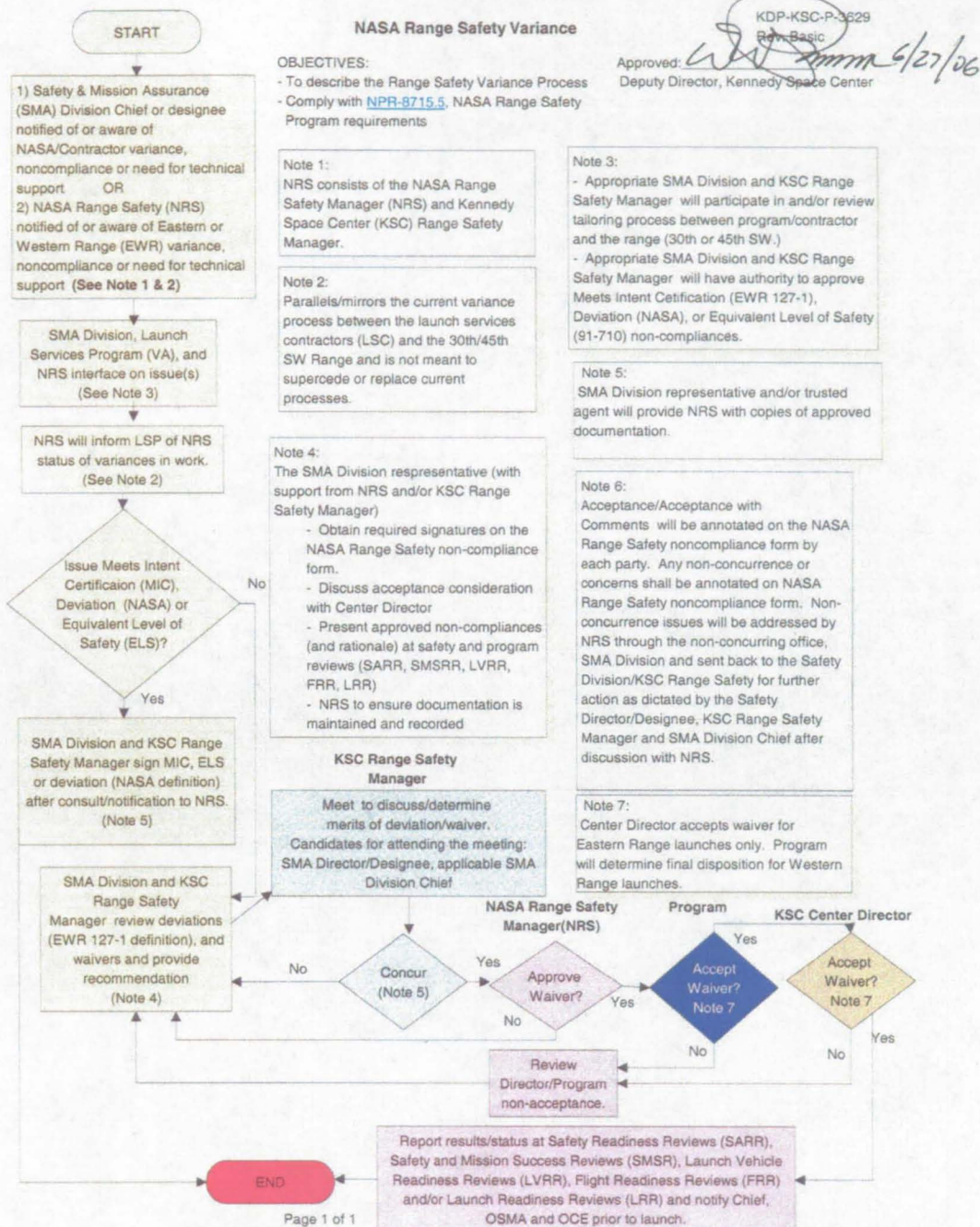


Range Safety Variance Process

During 2006, NASA Range Safety worked diligently to finalize [KDP-KSC-P-3629](#), NASA *Range Safety Variance* process as directed by [NPR 8715.5](#). The plan was signed in June 2006 and provided the opportunity to use the new process to document existing range safety non-compliances held by the Air Force Eastern and Western Ranges. NASA Range Safety obtained all past and current non-compliances related to the Launch Services Program and the Space Shuttle Program.

We conducted a review of the technical rationale used in the disposition of each variance, provided our own independent evaluation of the rationale, and documented all of them on the NASA Range Safety Variance Request form. NASA Range Safety also established a database and hard copy file of all documentation.

The process outlined in the graphic below is used for each new range safety related variance for both Launch Services Program and the Space Shuttle Program and will be used for the Constellation Program as well.



Range Safety Risk Process

A new procedure, KSC Space Flight Risk Assessment process, KDP-KSC-P-3628, outlining the process for managing range safety risks for launch and entry at Kennedy Space Center was approved in June 2006.

The objectives of the process are as follows:

- To ensure the safety of the Kennedy Space Center workforce and visitors during launches
- To comply with [KCA 1305](#), *Memorandum of Agreement Among the 45th Space Wing, The National Aeronautics and Space Administration's John F. Kennedy Space Center, and The Space Shuttle Program Office for Range Safety*
- To comply with [NPR 8715.5](#), *NASA Range Safety Program*

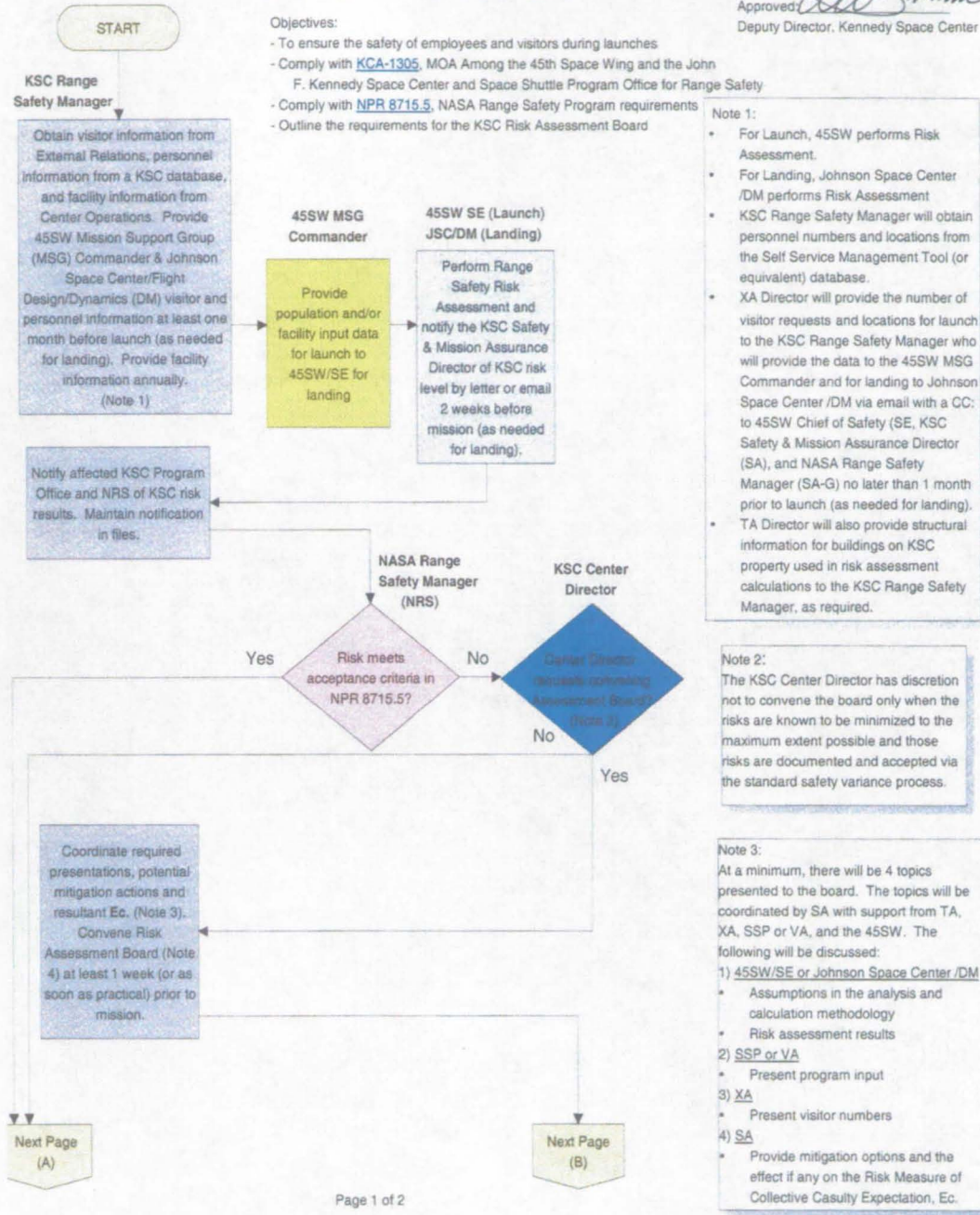
The process also outlines the requirements for the KSC risk assessment board should additional mitigation action be required to reduce risk to an acceptable level for launch or landing operations. The process flowpath is shown in the graphic below.

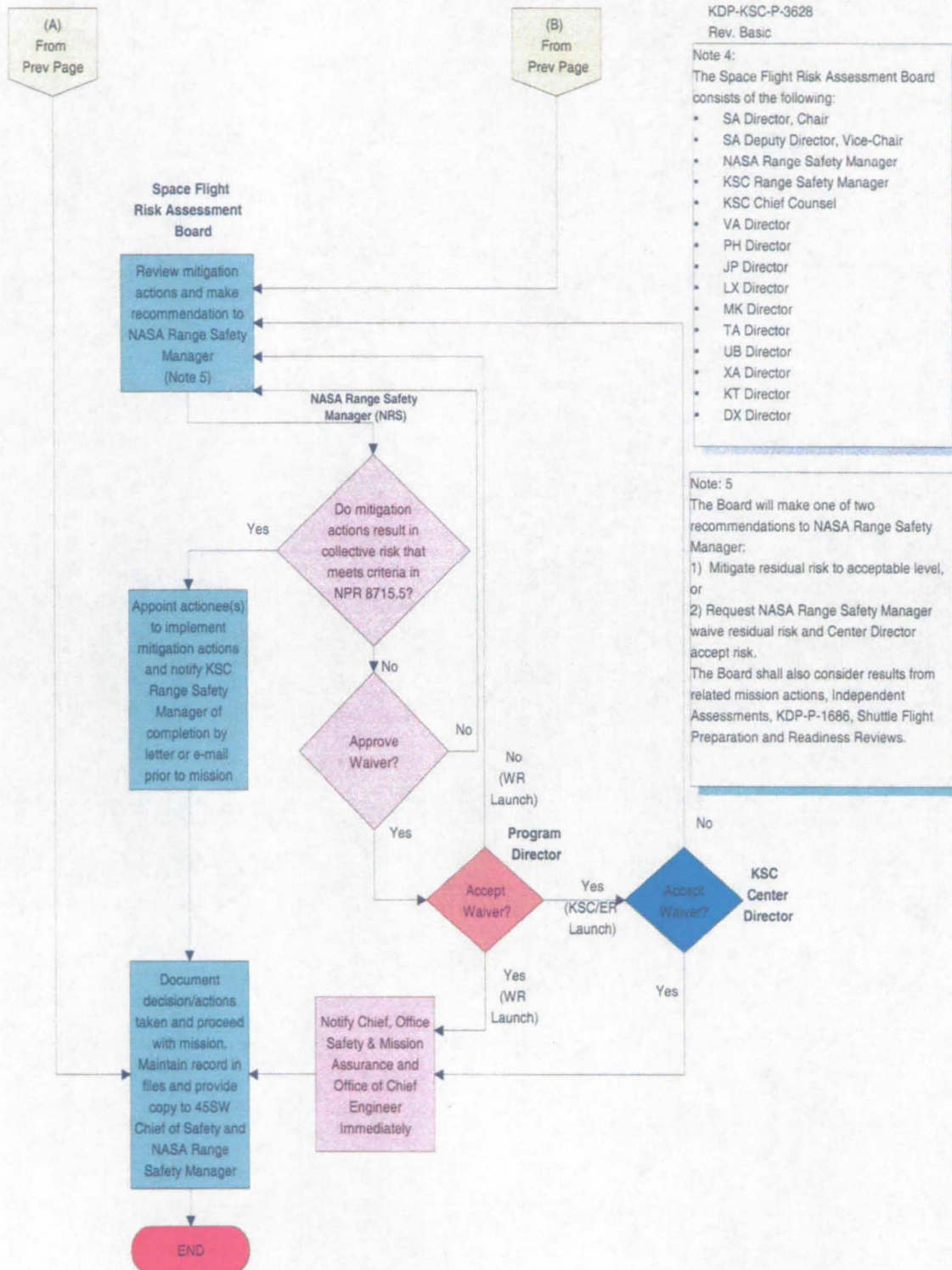
KSC Space Flight Risk Assessment Process

KDP-KSC-P-3628

Rev. Basic

Approved: *[Signature]*
Deputy Director, Kennedy Space Center





Range Safety Launch Support Policy

On 19 January 2006, NASA Range Safety supported the NASA Pluto New Horizons launch at the Eastern Range's Range Operations Control Center at Cape Canaveral Air Force Station. This was the first time NASA Range Safety supported a launch other than the Space Shuttle. This historic effort took many months of planning and negotiations between all parties to determine the appropriate amount of involvement, not to mention the coordination of resources required to support two additional console positions in the Mission Control Room at the Range Operations Control Center.

A New Way of Operating

Through agreements between NASA, the 45th Space Wing, and the 30th Space Wing, NASA Range Safety provides operational support to relay range safety information to NASA launch team managers, as well as ensuring NASA Procedural Requirements (NPR 8715.5) are met during pre-launch, launch, and post-launch operations. Currently, there is a Memorandum of Agreement between the 45th Space Wing, NASA/Kennedy Space Center, and the Space Shuttle Program that outlines the procedures for NASA Range Safety Support. We recently completed a draft Memorandum of Agreement with the 30th Space Wing Safety Office to formalize support at the Western Range.

This new way of operating bridges some of the gaps from the past. The processes allow for direct communications with the Air Force Commander's Advisory Board, Safety Advisors, and Mission Flight Control Officers on matters of range safety, such as flight safety systems, flight safety analysis, tracking and instrumentation outages and limitations, as well as user vehicle anomalies. With timely and more concise information, a launch abort or scrub may be avoided, saving time and money. However, the most important aspect of this cooperative effort is the fact that this type of partnership is the most practical and effective way to do business when it comes to ensuring public safety.

Challenges

Several challenges were associated with such a bold new approach. Providing console space in the respective range operations centers was one of the major hurdles of the new operations. This meant that Operations Directives that list range support requirements had to be updated to include the new NASA Range Safety positions. Furthermore, communication support plans and entry authorizations needed to be updated and approved to ensure full inclusion into the range safety process. It was vital that NASA Range Safety personnel have the capability to communicate with both the Air Force and NASA team on safety issues quickly and accurately.

Additionally, a process for receiving Air Force generated launch documentation to support launch activities needed to be in place. NASA Range Safety requested the same documents used by the Mission Flight Control Officers and Safety Technical Advisors. To ensure NASA Range Safety was in lock-step with the Range, it was determined that waivers and variances, the Launch Support Plan (Range Countdown Checklist), Mission Flight Control Officer Countdown Checklist, Estimated Coverage Plan for instrumentation, Flight Control Instrumentation Worksheet, Range Safety Operations Requirements and Supplements, and general and special Mission Rules as well as other documentation would be provided to ensure everyone was working from the same page for an orderly flow of events and discussions during the countdown.

Other processes were needed to ensure that NASA Range Safety personnel were included and advised of meetings, readiness reviews, and integrated crew exercises tied into pre-launch processes. Since the Program Support Managers are the Range focal point for launch support meetings as well as the liaison between the Range and the vehicle provider, they have proven invaluable in providing this information to NASA Range Safety.

Benefits

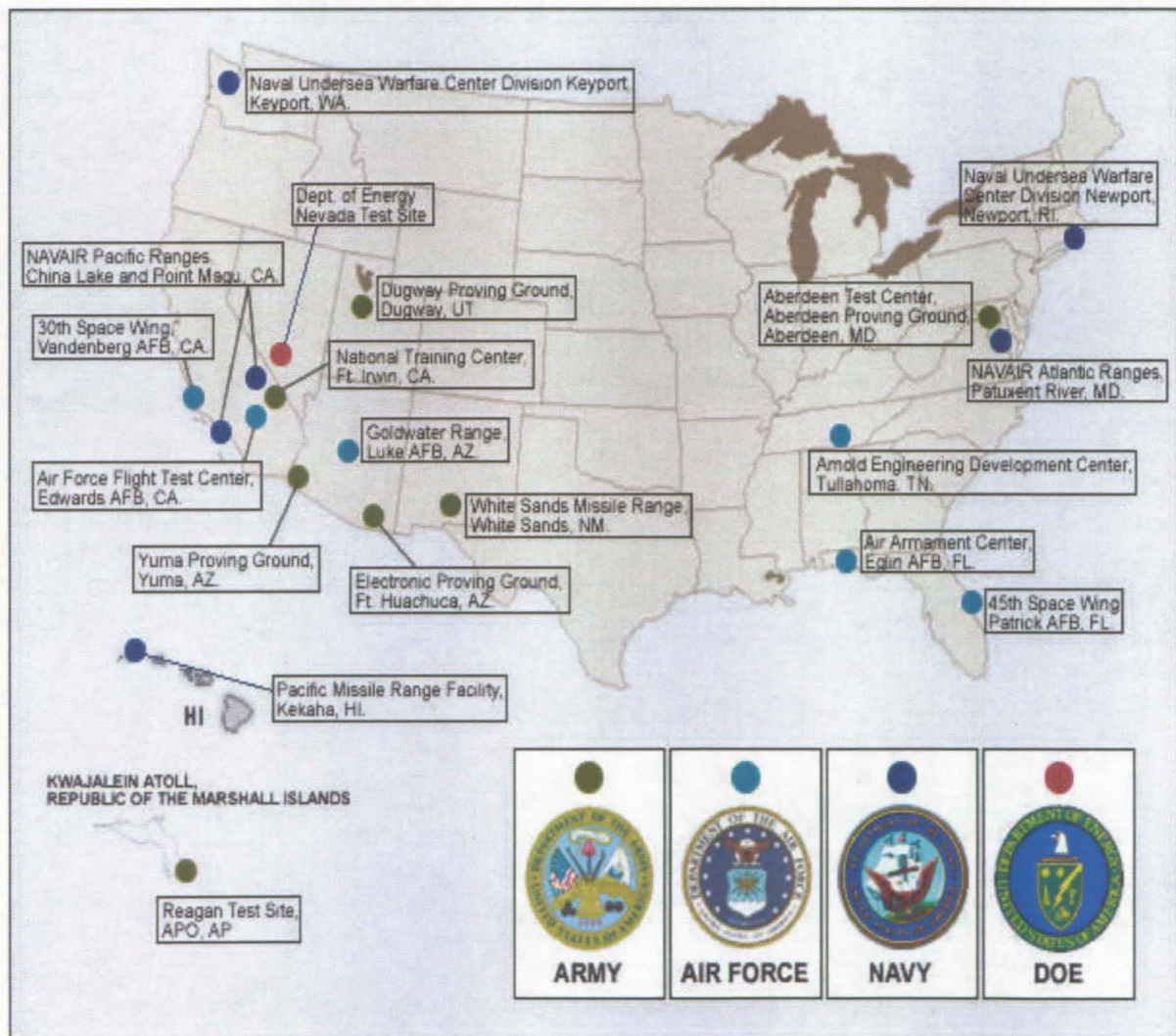
This cooperative effort was further demonstrated when NASA Range Safety supported two launches (Pegasus/ST-5 and Delta II/CloudSat-CALIPSO) at Vandenberg Air Force Base, California and STEREO mission launched from Cape Canaveral Air Force Station. To date this effort has paid many benefits, specifically opening the lines of communications and cooperation between NASA, the Air Force, and the Range User to new levels. With this solid foundation, our collective processes continue to evolve as we work together to ensure public safety.

Range Commanders Council

The Range Commanders Council is dedicated to serving the technical and operational needs of United States test, training, and operational ranges. The council was formed in August 1951 to preserve and enhance the efficiency and effectiveness of member ranges, thereby increasing their research and development, operational test and evaluation, and training and readiness capabilities. The responsibility of the Range Commanders Council is to proactively share insights and products with various services and Department of Defense organizations.

Member Ranges

Army, Air Force, Navy and Department of Energy ranges are shown in the graphic below and their locations identified in the following table.



Locations of Member Ranges

Army	Air Force	Navy	Department of Energy
Aberdeen Test Center, Aberdeen Proving Ground, Aberdeen, MD	30 th Space Wing, Vandenberg Air Force Base, CA	NAVAIR Atlantic Ranges, Patuxent River, MD	Department of Energy Nevada Test Site
Dugway Proving Ground, Dugway, UT	45 th Space Wing, Patrick Air Force Base, FL	NAVAIR Pacific Ranges, China Lake and Point Mugu, CA	
Electronic Proving Ground, Ft Huachuca, AZ	Air Armament Center, Eglin Air Force Base, FL	Naval Undersea Warfare Center Division Keyport, Keyport, WA	
National Training Center, Fort Irwin, CA	Air Force Flight Test Center, Edwards Air Force Base, CA	Naval Undersea Warfare Center Division Newport, Newport, RI	
Reagan Test Site, APO AP	Arnold Engineering Development Center, Tullahoma, TN	Pacific Missile Range Facility, Kekaha, HI	
White Sands Missile Range, White Sands, NM	Goldwater Range, Luke Air Force Base, AZ		
Yuma Proving Ground, Yuma, AZ			

Range Commanders Council Objectives and Organization

The primary objectives of the Range Commanders Council are listed below:

- Discuss and resolve common range issues in an organized forum
- Exchange information and ideas, thereby minimizing duplication
- Conduct joint investigations pertaining to research, design, development, procurement, and testing
- Coordinate major or special procurement actions
- Develop operational test procedures and standards for present and future range use
- Encourage the interchange of technical systems and equipment

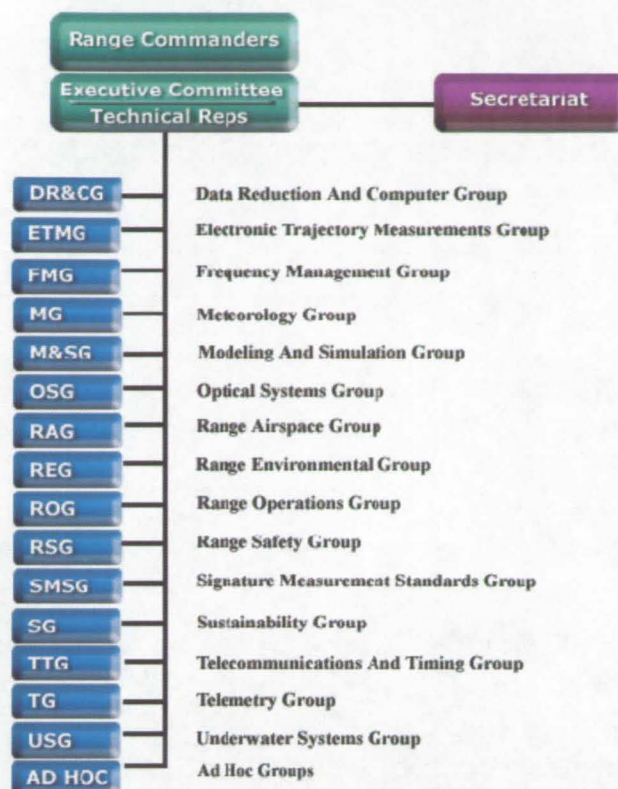
To meet these objectives, the Range Commanders Council is divided into a number of specialized groups organized to address technical issues of concern and interest to the various member ranges. Several committees can be formed under each group. Of particular interest to range safety are the Range Safety Group and two committees under that group.

- Flight Termination Systems Committee
- Risk Committee

Range Safety Group

Through standardization, development, and continuous improvement, the Range Safety Group supports the safe conduct of hazardous operations on test, training, and operational ranges and related facilities. The 98th Range Safety Group meeting was held at White Sands Missile Range in April. The main committee and the Flight Termination Systems Committee and Risk Committee met concurrently.

Highlights of the meeting included a special briefing and video of the autonomous flight safety system sounding rocket test conducted at White Sands Missile Range on April 5th and the tour of the range on the third day.



The Naval Air War Center, Patuxent River, Maryland hosted the 99th Range Safety Group meeting in October. The main committee and the Flight Termination Systems, Risk, and Laser committees met at that time. Highlights included special briefings by the Southern California Offshore Range and the Joint Strike Fighter Program, the election of new Range Safety Group officers, and a tour of Pax River. Walt Montieth, Air Armament Center at Eglin Air Force Base, was elected the new Range Safety Group Secretary. Michael Young moved from Vice Chair to Chair, and Greg Speth moved into the Vice Chair position. Southern California Offshore Range also petitioned for and received approval to join the Range Safety Group as an Associate Member.

Flight Termination Systems Committee. The Flight Termination Systems Committee provides a forum for all issues and technologies related to the flight termination system effort. One of the tasks the committee was asked to complete was the rewrite of RCC 319, *Flight Termination Systems Commonality Standard*. RCC 319 establishes common flight termination system design and testing requirements for different programs and different ranges. This document is being revised to update, clarify, and amend certain sections and requirements to reflect new technologies, studies, and lessons learned.

The task to rewrite RCC 319 began in 2003 and is expected to be completed in early 2007. Members of numerous ranges and organizations are involved in the rewrite to obtain a variety of inputs and ideas from many different sources and ranges. Other topics being discussed by this committee include emerging technologies such as the

enhanced flight termination system, autonomous flight safety system, and subminiature flight safety system as well as potential problems such as the radar interference to flight termination system receivers.

Risk Committee. In early 2004, the Range Safety Group initiated Phase II of a Risk and Lethality Commonality Team effort to revise RCC 321, *Common Risk Criteria for National Test Ranges*. Because injury criteria were not defined during Phase I of the Risk and Lethality Commonality Team effort, the Department of Defense major range and test facility bases have diverged from use of the standard since it addresses acceptable risk criteria pertaining only to fatalities. The second phase of the Risk and Lethality Commonality Team effort has focused on establishing acceptable risk criteria based on casualties.

The Range Safety Group also recommended that RCC 321 be updated and expanded to include flight safety hazards in addition to inert debris. The Risk and Lethality Commonality Team II was initially established as an ad hoc committee under the Range Safety Group. However, after a few meetings, the identification of additional risk-related topics, and the more detailed development of tasks, the need for a standing committee was realized. In February 2005, the Risk and Lethality Commonality Team was renamed the Risk Committee with a specific objective to rewrite RCC 321.

The committee has spent the last three years focusing on establishing updated acceptable risk criterion and developing detailed supporting rationale for inert debris and other range hazards, including distant focusing overpressure and toxics. The group has also decided to establish an aggregated risk criterion, evaluating the combination of all launch hazard risk against one acceptable level. The group has examined and incorporated discussion and/or criterion for the following topics:

- Major activities required to conduct the entire risk management process and considerations to address hazards beyond just inert debris
- Requirements for computational models used to analyze the risks posed by inert and explosive debris
- Hazard thresholds for inert and explosive debris as well as screening criteria for other hazards including toxics and distant focusing overpressure
- Aircraft and ship risk management requirements
- Catastrophic risk
- Space craft protection

In October 2006, the Risk Committee submitted the final draft of the revised RCC 321 to the Range Safety Group for review. The revised document is expected to follow the standard Range Commander Council issue process. The Risk Committee is currently in the process of developing a new task statement for the upcoming session with potential topics to include:

- Space craft protection to include satellite protection beyond orbital insertion, safety responsibility for space systems, and space craft protection for exo-atmospheric and orbital debris hazards
- Reusable launch vehicle and other controlled reentry related issues
- Conditional risk criterion for foreseeable conditions

- Treatment of uncertainty in risk assessments
- Asset protection
- Hazard thresholds for land vehicles
- Assessment and application of catastrophic risk
- Minor injuries

These topics will be further developed at the next Range Safety Group/Risk Committee meeting in April 2007 to be co-hosted by NASA – Kennedy Space Center and Patrick Air Force Base.

NASA Range Safety will continue to work with the Range Commanders Council and the various ranges that comprise the forum to ensure that NASA is involved in the new, groundbreaking technologies as well as potential issues that could change the way we send astronauts into space.

Common Standards Working Group

The Common Standards Working Group is an interagency partnership established to develop, publish, and maintain Air Force and the Federal Aviation Administration, Associate Administrator for Commercial Space Transportation common launch safety requirements and practices to protect the public during launch and re-entry operations.

The charter for the Common Standards Working Group implemented the *Memorandum of Agreement Between the Department of the Air Force and Federal Administration on Safety for Space Transportation and Range Activities* at the direction of the Senior Steering Group. The memorandum, dated 16 January 2001, stated that the AF and the FAA would work together to achieve common safety requirements for launches.

The tangible benefits from the creation of common safety standards include a stable framework of safety requirements for the U.S. space launch industry and minimal administrative burdens for the government and commercial sectors. Another welcome by-product is the creation of a system of checks and balances between the two agencies.

Membership

The working group is a government-only forum. Commercial launch industry representatives are not permitted to participate due to the Department of Transportation policy regarding rulemaking. Membership in the group consists of representatives of the Air Force and Federal Administration Association organizations that are responsible for the development and implementation of launch and re-entry safety requirements, practices, activities, and policies and includes.

- 14th Air Force, Safety, A3
- 30th Space Wing, Safety
- 45th Space Wing, Safety
- Air Force Space Command
- Air Force Systems Command
- Director of National Security, Space Integration, Office of the Under Secretary of the Air Force
- Federal Aviation Administration, Associate Administrator for Commercial Space Transportation
- Headquarters United States Air Force
- Space and Missile Center

NASA, the National Reconnaissance Office, and the Missile Defense Agency are also current members of the group.

Senior Steering Group

The Senior Steering Group provides senior executive leadership and guidance to the Common Standards Working Group to accomplish its objectives. The Senior Steering

Group meets semi-annually, or more frequently as needed, and is co-chaired by the following:

- The Federal Aviation Administration Associate Administrator for Commercial Space Transportation
- The Director of National Security Space Integration, Headquarters United States Air Force
- The Director of Space Operations and Integration, Headquarters United States Air Force
- The Director of Air and Space Operations, Headquarters Air Force Space Command

Past Accomplishments

The Common Standards Working Group has made significant progress since its inception, drafting and publishing the *Range Safety User Requirements Manual* (AFSPCMAN 91-710) in July 2004. Additionally, the Federal Aviation Administration issued its first *Notice of Proposed Rulemaking* in October 2000. It then issued a supplemental notice in July 2002 and published and posted its second supplemental notice in 2003. In conjunction with the new rule, the Common Standards Working Group also developed a Launch Safety Site Assessment and a Memorandum of Understanding between the FAA and the Air Force for resolving requests for relief from common launch safety requirements.

Also, in 2003, the working group agreed on a framework for determining probabilities of failure for new expendable launch vehicles. The group established a list of factors that are requirements and practices used by the Federal Aviation Administration and the Air Force to protect public safety during launch and re-entry. The Federal Aviation Administration requirements have been codified in 14 Code of Federal Regulations, Chapter III.

At Air Force Space Command ranges, the common safety standards are implemented through Air Force Space Command Range Safety documents. Since the vehicles in question were new with little existing empirical data, it was determined that initial evaluations would be conducted based in part on data from vehicles developed and launched under similar circumstances. An independent assessment of the proposed requirements and methods was conducted, and the Common Standards Working Group published the final guidelines in 2004.

Current Projects

The Common Standards Working Group and its committee are currently working on the following projects.

AFSPCMAN 91-711. Recently, the Common Standards Working Group developed AFSPCMAN 91-711, *Launch Safety Requirements for Air Force Space Command Organizations*. This document is scheduled for publication in 2007. The manual describes the Launch Safety (formerly known as Range Safety) authorities, responsibilities, and functions of organizations internal to Air Force Space Command,

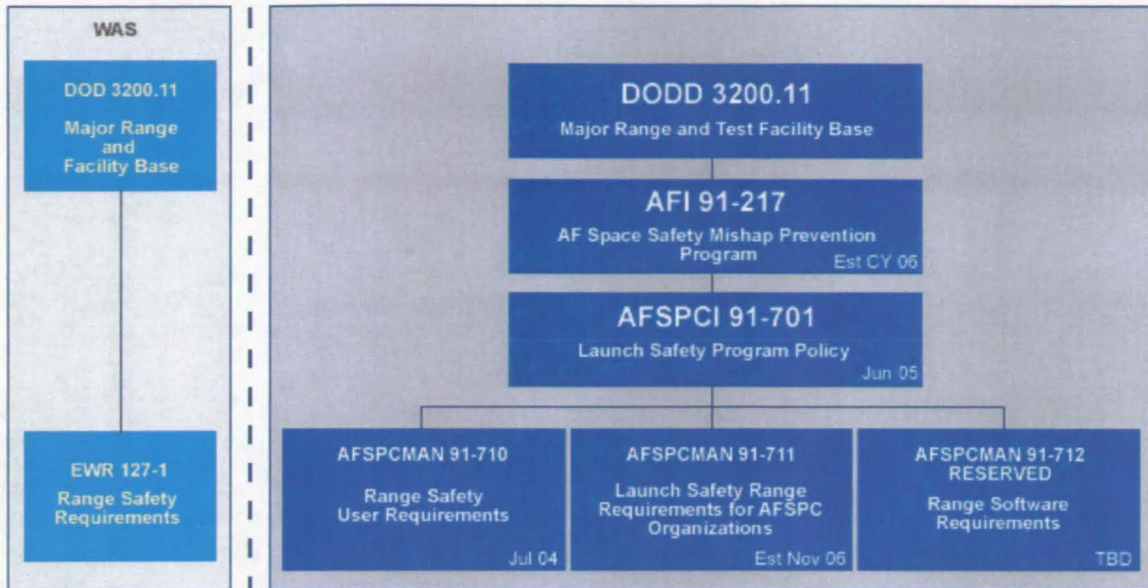
including defining and implementing the Launch Safety Program policy and responsibilities for Space Command ranges.

AFSPCMAN 91-712. Headquarters Air Force Space Command Safety made a decision to revise and combine the computer and software requirements for Range Users (currently in AFSPCMAN 91-710) and the computer and software requirements for Range Operators and Acquirers into a single document. These requirements will be published as AFSPCMAN 91-712, *Range Software Requirements*. Space Command convened the Common Standards Working Group to develop and coordinate these requirements. The draft computer and software requirements were sent to industry, Range Users (including NASA), and Range Operators and Acquirers for review and comment. This document is scheduled for publication in 2007.

Reusable Launch Vehicles. The Reusable Launch Vehicle (RLV) Working Group was formed in April 2006 to develop public safety requirements for the launch and recovery of reusable launch vehicles. Membership includes the Air Force and Federal Aviation Administration, with participation from NASA. The group was formed for the following reasons:

- When AFSPCMAN 91-710, *Range Safety User Requirements*, was released in July 2004, reusable launch vehicle requirements had not been adequately addressed.
- When the potential for reusable launch vehicle users on Air Force Space Command ranges increased, Air Force and Federal Aviation Administration leadership expressed their desire that reusable launch vehicle safety requirements be developed expeditiously to aid potential users in their design efforts.
- The flight of Spaceship One showed that entrepreneurs developing reusable launch vehicles is becoming a reality.
- The Space Shuttle Columbia accident revealed that safety concerns for the public during launch vehicle reentry needed to be addressed in more detail.

The Reusable Launch Vehicle Working Group meets weekly via teleconferences and has initiated development of public safety requirements for unmanned reusable launch vehicles. This effort began in October 2006, and development of safety requirements for manned reusable launch vehicles began in November 2006. The goal is to have a full set of public safety requirements for reusable launch vehicles developed by early 2007 for incorporation into AFSPCMAN 91-710 and Federal Aviation Administration's Reusable Launch Vehicle Public Rule. The figure below shows the evolution of the major safety documents from EWR 127-1 to the 91 document series.



NASA Range Safety has been an integral part of the Common Standards Working Group since 2004. As new and emerging space launch technologies surface, the group will continue to provide a forum through which the Air Force, the Federal Aviation Administration, NASA, and other government agencies can communicate on further development and implementation of common range safety standards. The goal of this group has been, and will always be, to maintain public safety in all phases of launch activities.

Unmanned Aircraft Systems Working Group Update

In August of 2005, the Kennedy Space Center's Applied Technology Directorate formalized activities for the development of an unmanned aircraft systems program to support future missions at Kennedy Space Center, Patrick Air Force Base, and Cape Canaveral Air Force Station. To aid in meeting program requirements, the Air Force's 45th Space Wing Safety Office, the Kennedy Space Center Range Safety Office, and the Applied Technology Directorate formed a working group to develop three joint initiatives:

- Cape Canaveral Spaceport Unmanned Aircraft System Range Safety Requirements
- Cape Canaveral Spaceport Unmanned Aircraft System Flight Operations Manual
- Cape Canaveral Spaceport Unmanned Aircraft System Concept of Operations.

Working Group Goals

The working group's efforts are supporting near-term goals of Kennedy Space Center and the 45th Space Wing to provide enhanced mission support from mobile aerial platforms. Specifically, the goals are to incorporate unmanned aircraft systems to supplement existing range functions of tracking and surveillance and to respond on short notice to supplement existing range functions.

The joint documentation will provide requirements for all unmanned aircraft system operations to be conducted at Kennedy Space Center, Cape Canaveral Air Force Station, and Patrick Air Force Base. Although NASA currently conducts unmanned aircraft systems operations at Dryden Flight Research Center, Goddard Space Flight Center/Wallops Flight Facility, Ames Research Center, and Langley Research Center, Kennedy Space Center and the 45th Space Wing have been contracted by several parties interested in conducting operations at the Cape Canaveral Spaceport.

Kennedy Space Center and the 45th Space Wing recognize that Cape Canaveral Spaceport poses many unique challenges due to the complexities of human space flight and expendable rocket flight operations as well as the existence of a large number of high-valued assets, such as launch complexes, fuel storage facilities, launch vehicles, and supporting equipment within the confines of Kennedy Space Center, Patrick Air Force Base, and Cape Canaveral Air Force Station. These challenges require a fundamental change from Range Safety's current paradigm for launching space vehicles to one that includes unmanned aircraft systems operations.

Document Review

To address these challenges, the working group conducted an extensive document review to aid in determining the compulsory subtopics to be addressed in a requirements document and a flight operations manual. Once completed, an exhaustive outline was developed and sections were assigned to personnel to construct requirements based on subject matter expertise. The working group was further challenged to incorporate future concepts of operating unmanned aircraft systems in the National Airspace.

Responsibilities

The 45th Space Wing will be responsible for managing the requirements for unmanned aircraft systems flight operations at Kennedy Space Center, Patrick Air Force Base, and Cape Canaveral Air Force Station through the Cape Canaveral Spaceport Unmanned Aircraft Systems Range Safety Requirements document. The 45th Space Wing Safety Office has compiled a draft requirements document and it is in the data review/update phase to ensure completeness, accuracy, and clarity.

Kennedy Space Center will be responsible for managing the process for unmanned aircraft systems flight operations at Kennedy Space Center, Patrick Air Force Base, and Cape Canaveral Air Force Station through the Cape Canaveral Spaceport Unmanned Aircraft Systems Flight Operations Manual. The Applied Technology Directorate has compiled the draft Flight Operations Manual that describes the processes and procedures for gaining unmanned aircraft systems flight operations approval from NASA and the 45th Space Wing. This manual includes an air worthiness and range safety certification approval process; describes operational agreements between NASA, the 45th Space Wing, and the Federal Aviation Administration; and lists project and program interfaces and standards.

The Cape Canaveral Spaceport Unmanned Aircraft Systems Concept of Operations document describes a generic model for unmanned aircraft systems requirements and flight operations at Cape Canaveral Spaceport. Kennedy Space Center will be responsible for developing and maintaining this document. The document will assist the potential user and the range by providing a generic end-to-end model of mission timelines, support staff, equipment, and range services for a typical unmanned aircraft systems mission at Cape Canaveral Spaceport. The draft will be completed by the Applied Technology Directorate the first quarter of 2007.

Next Phase

The next phase for Cape Canaveral Spaceport unmanned aircraft systems document reviews will expand the working group to include members from the Federal Aviation Administration, other NASA centers, and Department of Defense ranges to ensure accuracy, consistency, and comprehensiveness.

In the future, unmanned aircraft systems operations at Kennedy Space Center, Patrick Air Force Base, and Cape Canaveral Air Force Station will support mission requirements, program requirements, and instrument testing for NASA, the 45th Space Wing, other federal and state agencies, educational institutions, and commercial entities. It is not the intention of NASA or the 45th Space Wing to authorize flight tests for the sole purpose of testing the flight capability of an unmanned aircraft systems airframe. The working group is striving to encompass all aspects of Range Safety that will maximize the protection of personnel, property, other aircraft, and national assets.

Launch and Landing Plans for the Space Shuttle

NASA Range Safety initiated an interagency comprehensive update of Kennedy Space Center specific risk management criteria for the launch and landing of the Space Shuttle, as well as standardized landing criteria for Johnson Space Center, Edwards Air Force Base, and White Sands Missile Complex. The results of these efforts culminated in the update of two Kennedy Space Center Plans: KSC-PLN-2805, Range Safety Risk Management Plan for the Launch and Landing of the Space Shuttle and KSC-PLN-2804, KSC Range Safety Implementation Plan for the Landing of the Space Shuttle and the backup landing sites plans.

The Risk Management Plan

The Kennedy Space Center *Range Safety Risk Management Plan for Launch and Landing of the Space Shuttle* outlines the agency's risk management process consisting of risk assessment, hazard containment, and risk mitigation strategies for launch and landing of the Space Shuttle, while addressing the NASA policy regarding range safety (NPR 8715.5 *Range Safety Program*). It is anticipated that Kennedy Space Center pre-launch and landing planning will result in meeting all the NPR launch criteria for falling debris, toxics, and far-field overpressure hazards.

The plan will be updated by the Kennedy Space Center Range Safety Manager at least every two years to reflect current operations and risk levels. The risk management process for launch and landing the Space Shuttle includes established Air Force and NASA processes using containment and risk analysis as well as a Kennedy Space Center risk assessment process to address potential situations if residual risk violates policy criteria contained in NPR 8715.5. This risk management process involves pre-launch and landing preparation and real-time communications between the Air Force and Kennedy Space Center and results in a strong risk management methodology.

The Implementation Plan

The Kennedy Space Center *Range Safety Implementation Plan for Landing of the Space Shuttle* outlines hazard containment and risk mitigation strategies used to implement the *Launch and Landing Risk Management Plan for the Space Shuttle* in accordance with NPR 8715.5. The goal is to meet all the individual and collective risk criteria for falling debris during nominal end-of-mission, return-to-launch-site operations. The plan is a combined effort, with Johnson Space Center providing the detailed risk analysis and Kennedy Space Center providing input data and assessing the results.

Kennedy provides Johnson with a population database for Kennedy Space Center (visitors and workforce) for use in their entry risk model. This data provides the expected numbers of people as well as their planned locations during entry. In turn, Johnson Space Center/Flight Design and Dynamics Division provides Kennedy Space Center with a detailed listing of expectation of casualty results for the public and workforce on Kennedy Space Center property. The data also highlight locations of high individual and collective casualty expectation and establishes keep-out zones that identify areas within which the individual probability of casualty (P_c) is greater than the NPR 8715.5 criteria permits.

The Kennedy Space Center Range Safety Manager, External Relations, Protective Services, and Shuttle Processing/Launch and Landing worked together to develop this

plan that addresses the requirement to secure specified keep-out zones and to notify visitors and nonmission-essential workforce of contingency actions during the launch and landing of the Space Shuttle.

Flight Safety System Challenges

Range Safety is often faced with many challenges when trying to ensure the protection of the public, the local workforce, and property. These challenges must be met with steadfast determination and urgency in order to ensure that public safety and mission success are preserved. One of the biggest challenges Range Safety dealt with in 2006 was the frequency interference issue between onboard flight termination system receivers used to independently terminate an errant vehicle and other radar systems used in a local area for various mission related and non-mission related support.

Frequency Dilemma

As noted above, one of the Range Safety's most important and ongoing issues involves flight termination system frequencies. For many years, 416.5 megahertz has been used as a flight termination system frequency for many years at the Eastern and Western ranges. However, because of overcrowding of that frequency in the 1990s, the National Telecommunications and Information Administration directed the Department of Defense to stop use of 416.5 megahertz for flight termination systems no later than the last day of calendar year 2006.

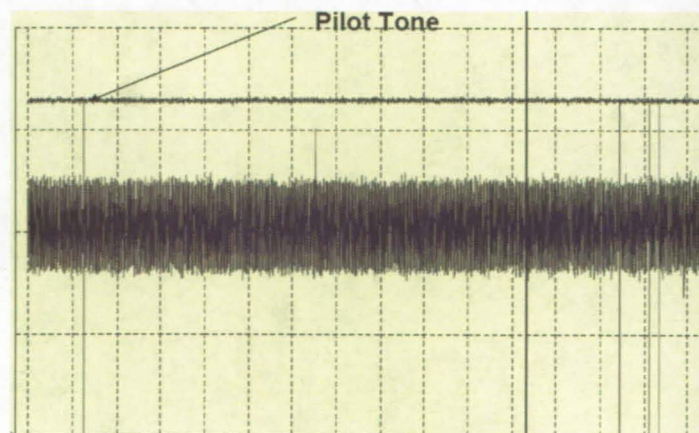
The National Telecommunications and Information Administration announced this change in August 2000. The reason for the change is that ultra high frequency wideband systems, such as flight termination systems, are required to operate in the 420-450 megahertz spectrum. 400-420 megahertz is reserved for narrow band systems. So the Eastern and Western ranges chose 421 megahertz as the center frequency to be used for flight termination systems on launch vehicles.

Interference at 421-450 Megahertz

During two recent launches at Vandenberg Air Force Base, it was discovered that the flight termination system receivers were undergoing interference problems. After research and several studies were performed, it was found that a high power radar system at Beale Air Force Base over 300 miles away was the cause of the interference. Beale Air Force Base maintains an upgraded early warning radar system called PAVE PAWS that operates in the same frequency of 400-450 megahertz. This upgraded early warning radar system is much more powerful than the command transmitter sites used for range operations.

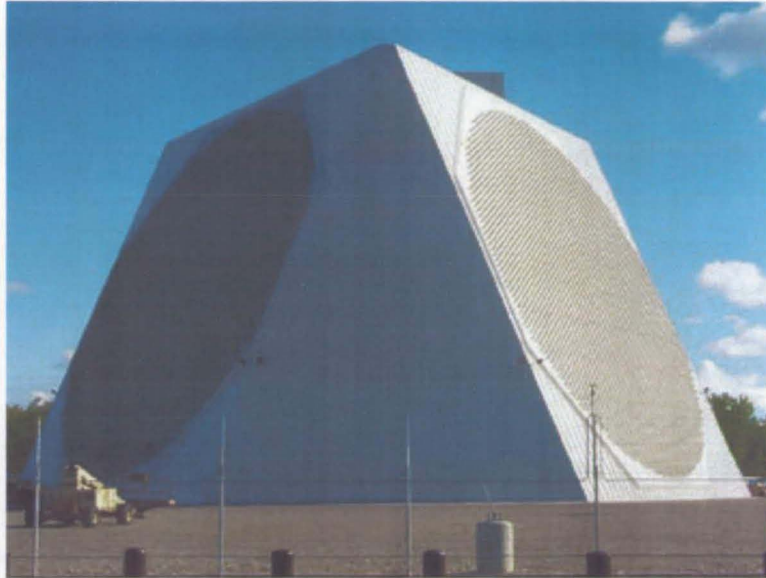
If the radar is operating at the same frequency as the command transmitter sites and command receiver decoders, the command receiver decoders could experience interference and be unable to process commands from the command transmitter site. At worst, this interference could prevent the termination of an errant vehicle that could be endangering public safety.

The graph shows the interference between PAVE PAWS at Beale Air Force Base and a secure receiver that is used on various



launch vehicles. The pilot tone is used to check the health and status of the receiver; a pilot tone dropout means that the receiver is not able to receive and/or process commands at that moment.

PAVE PAWS systems are also located at Clear Air Force Base in Alaska (see right) and Otis Air National Guard Base at Cape Cod, Massachusetts. The PAVE PAWS radars located at Clear and Cape Cod are early warning radars, not upgraded early warning radar like the Beale radar. Even though these early warning radars are not upgraded yet, it is possible that they could still pose interference issues with launches from the Eastern and Western ranges.



Beale Air Force Base has mitigated the interference before

by “blanking out” certain segments of the operating frequencies, but this may not be a possibility much longer because these radars lose a great amount of their capability when mitigated. Although PAVE PAWS is the primary focus of this interference issue, other radars that can cause problems to range operations may be operating in this frequency band. Studies are being performed to identify the characteristics of various radar systems that could affect range operations.

Options

Several options are currently being examined that would help correct the interference problems. Some of the possible solutions and their future implementation are described below.

Option 1. One option is to continue the use of 416.5 megahertz as the main flight termination system frequency. 416.5 megahertz has been used for many years and very few problems exist at this frequency. Ranges are currently designed to handle this frequency, so no new hardware or upgrades would be necessary to support 416.5 megahertz.

However, the National Telecommunications and Information Administration has instructed that 416.5 megahertz should not be used as a flight termination system frequency. To use this frequency for flight termination system operations, ranges must submit an “Exception to Policy” to the National Telecommunications and Information Administration and receive approval.

Option 2. Another option is to use 421/425 megahertz as the flight termination system frequency. To use this frequency, some sort of mitigation effort must be made to the PAVE PAWS radars to ensure that all commands can get through without interference. However, as stated earlier, PAVE PAWS loses a great amount of its capability when mitigated, so Beale Air Force Base may not always continue to mitigate the radar.

If the radar cannot be mitigated to negate the interference, one way to improve the probability of getting commands through is to use secure receivers. Secure receivers are still susceptible to PAVE PAWS, but are more robust than standard tone receivers. Standard tone receivers are highly susceptible to the interference from PAVE PAWS and would have significant trouble processing commands if interfered with by PAVE PAWS.

Option 3. The next option is to move to an entirely new frequency band. The Range Commander's Council Frequency Management Group, Air Force Space Command, and some Range Users are leading studies to look at a new frequency band, specifically in the 370-380 megahertz range. If approved for flight termination system use by the National Telecommunications and Information Administration, dedicated frequencies would be authorized within this range for use only by flight termination system users.

Migrating to a new band in the 370-380 megahertz region with flight termination system operations as the primary user reduces the probability of interference. The high power radar systems such as PAVE PAWS do not operate in this region. For this option to be realized, several criteria must be considered. First, the Eastern and Western ranges would have to upgrade their ground equipment to support the migration to a new band. The current ground equipment is capable of tuning down to 416.5 megahertz but would not be able to accommodate the new lower frequency of 370-380 megahertz.

Additionally, the airborne side of the equation would also have to be upgraded. The new frequency band of 370-380 megahertz will cause the development of a new receiving system. Antennas, couplers, and receivers would have to be replaced to accommodate the move. This option will take time and money to test and procure new equipment, but the end product would be a newly designed system that would operate in a frequency band where the flight termination system is the primary user, resolving the interference issues seen today.

Option 4. Another option that would alleviate the interference issues is a future system that is currently under development, the autonomous flight safety system. The autonomous flight safety system is immune to the previously discussed interference issues because it operates using the Tracking and Data Relay Satellite System, Ku-Band, and S-Band. The vehicle would use an onboard autonomous system that detects when and if the vehicle violates pre-established flight safety rules.

If the vehicle violates the pre-determined accepted flight rules, the autonomous system responds and initiates the ordnance train. This system is not expected to be available for use on expendable launch vehicles or similar vehicles until late 2008 or 2009. In theory, the autonomous flight safety system could act alone and be the only method of initiating a destruct command, eliminating the need of a flight termination system frequency for termination. Although the autonomous flight safety system could theoretically be the sole means of initiating a destruct, right now the system is viewed mainly as a potential downrange application to be used in conjunction with an up-range (human-in-the-loop) command destruct system.

Current Status

Both the Eastern Range and Western ranges are working hard to come up with an answer to this issue. In 2006, each range submitted an "Exception to Policy" to remain at 416.5 megahertz. The Western Range has received approval to stay at 416.5 megahertz for all launch vehicles until the end of calendar year 2008. After this date, the Western Range must move to the appropriate frequency band whether it is 420-450 megahertz or a new band such as 370-380 megahertz or submit a new "Exception To Policy." The Eastern Range has submitted an "Exception To Policy" to stay at 416.5 megahertz until the end of calendar year 2010; this "Exception To Policy" has not been approved as of this writing.

The Shuttle program has received waiver approval to continue the use of 416.5 megahertz until the end of program; however the National Telecommunications and Information Administration stipulated that all follow-on programs had to comply with its mandate to move to 420-450 megahertz. NASA Range Safety is working closely with the Department of Defense, Air Force Space Command, and industry to ensure that a viable and robust solution is chosen that will not only alleviate the problems seen with frequency interference, but also improve the overall confidence and reliability of flight termination systems.

Independent Assessments

Orbital Sciences Corporation Programmatic Audit and Review

In 2006, the NASA Headquarters Office of Safety and Mission Assurance, Review and Assessment Division performed a compliance verification audit of Orbital Sciences Corporation's expendable launch vehicle contracts. The specific objective of the audit was to verify compliance to NASA's Safety and Mission Assurance requirements imposed within Orbital Sciences Corporation Small Expendable Launch Vehicle Services contract, NAS1099005, and the NASA Launch Services contract, NNK05LB04B.

The NASA Audit Team focused on the following six key areas within the contract: management; product control; process control; purchasing; safety, reliability, and quality; and launch complex. The audit was conducted at three major Orbital Science Corporation sites: Dulles, Virginia (April 24-28); Chandler, Arizona (May 8-12); and Vandenberg Air Force Base, California (May 15-19). The audit team at Vandenberg is shown in the photograph below.



Audit Team at Vandenberg Air Force Base

Launch Complex Team

The NASA Range Safety Office participated on the Launch Complex Team to assess Orbital Sciences Corporation's range safety and launch operations safety elements for compliance with the contracts and Orbital Sciences Corporation corporate policies, plans, procedures, and practices. Team members were Mike Dook, Lead (NASA Headquarters, Office of Safety and Mission Assurance), Jon Mullin (NASA Headquarters, Office of Safety and Mission Assurance), Tom Palo (Kennedy Space Center, Safety and Mission Assurance), and Marv Becker (SRS Technologies, Kennedy Space Center).

Basis for Assessment

The assessment was based on observations of objective evidence; reviews of written procedures, records, and reports; inspections of Orbital Sciences Corporation facilities

and launch vehicle flight hardware; and interviews with key personnel. The Launch Complex Team also reviewed the contracts and related documents to observe how those documents reflect current NASA policy and requirements related to range safety and the safety of launch operations. Mr. Dook and Mr. Mullin participated in the review at all three Orbital Sciences Corporation facilities. Mr. Palo and Mr. Becker joined the Launch Complex Team for the reviews at Chandler and Vandenberg.

Orbital Sciences Corporation—Dulles, Virginia

The Launch Complex Team's primary point of contact while at Dulles was the Principal Safety Engineer for Pegasus and Taurus. The Principal Safety Engineer is responsible for ensuring that the requirements related to flight safety are satisfied for each Pegasus and Taurus launch. This includes all required coordination with the appropriate range safety organizations involved in each launch. The Principal Safety Engineer had been in that position for less than a year, but the person who held that position for the previous six or more years was available for consultation. The Launch Complex Team found these individuals to possess comprehensive knowledge of the Pegasus and Taurus launch vehicles as well as the NASA contracts and Orbital Sciences Corporation's approach to satisfying the associated requirements. The Launch Complex Team reviewed the corporation's corporate policy and internal safety requirements documents, Pegasus and Taurus program safety plans and procedures, documentation of mission specific safety decisions, and records of the corporation's coordination with range safety organizations on flight termination system and other range safety and launch operations related issues.



Orbital Sciences Corporation—Chandler, Arizona

At Chandler, the primary point of contact for the Launch Complex Team was the Safety Manager for Orbital Sciences Corporation's Launch Systems Group. The Safety



Manager oversees Orbital Sciences Corporation's safety program as it pertains to the development, production, and operation of Orbital Sciences Corporation launch vehicles including Pegasus and Taurus. The Launch Complex Team also spent significant time with the Principal Engineer for Industrial Safety at the Chandler facility. The team inspected high bays, workshops, and explosives storage facilities. The team also reviewed corporate policy and internal safety requirements documents, Pegasus and Taurus program

safety plans and procedures, documentation of mission specific safety decisions, documentation of safety related engineering changes, and records of the corporation's coordination with range safety organizations on flight termination system and other range safety and launch operations related issues.

Orbital Sciences Corporation—Vandenberg Air Force Base, California

At Vandenberg, the primary point of contact for the Launch Complex Team was the Principal Safety Engineer for Orbital Sciences Corporation's Vandenberg Operations. This engineer is responsible for the corporation's safety program at the Vandenberg facility and for coordinating with the Air Force on facility and operational/ground safety concerns associated with preparing Orbital Sciences Corporation launch vehicles for flight. The Principal Safety Engineer at Vandenberg also assists the Principal Safety Engineer for Pegasus and Taurus in resolving any flight safety concerns. The Launch Complex Team had significant discussions with the corporation's Safety, Reliability and Quality Assurance Director and Chief Engineer.

The team inspected Building 1555, which Orbital Sciences Corporation occupies on Vandenberg Air Force Base under a Commercial Space Launch agreement. The team reviewed facility safety elements, including fire protection, explosive safety, and lightning protection. The team also inspected the flight hardware currently being processed in Building 1555, which included the Pegasus Stages 1, 2, and 3 that will be used for NASA's [Aeronomy of Ice in the Mesosphere](#) mission. The Launch Complex Team walked down the flight termination system components currently installed on those stages. The team reviewed the safety inspection process implemented at Vandenberg, documentation of mission specific safety decisions, documentation of safety related engineering changes, and records of the corporation's coordination with the Air Force range safety organization on facility safety and launch operations related issues.



Audit Results

The audit results were briefed to the Launch Services Program and Kennedy Space Center management, and all range safety related findings will be tracked to closure by Kennedy Space Center Safety and Mission Assurance. The audit final report, dated 7 July 2006, and all findings can be accessed at the NASA Process Based Mission Assurance website <https://secureworkgroups.grc.nasa.gov/> under the ELV PA&R Compliance Verification Audits Enhanced Secure Work Group.

Common Analysis Tools Development

Public safety risk is evaluated for each NASA mission and must meet acceptable risk criterion as described in NASA Procedural Requirement 8715.5; *Range Safety Program*. Historically, each NASA Center was unique in its methodologies and approaches for determining risk. Some Centers developed in-house risk modeling capabilities while others relied on risk models developed and run by other agencies.

In September of 2006, range safety representatives from NASA Headquarters and Centers met to discuss current risk modeling capabilities and current needs and to determine a way ahead for future development. The group, now referred to as the *NASA Range Safety Analysis Tools Development Committee*, quickly identified the need to communicate and share resources with other Centers.

Standardizing Risk Assessment Methods and Processes

Standardization of the methodologies and processes used to assess risk is at the forefront of this committee's charter. Before the issuance of the procedural requirement in July of 2005, Centers were responsible for determining appropriate acceptable risk criteria for application to their missions. Public safety risk associated with missions launched from Department of Defense ranges was not necessarily the responsibility of NASA since Department of Defense Directive 3200.11, *Major Range and Test Facility Base*, places the burden of public safety risk solely on the Range Commander. Upon issuance of the NASA procedural requirement, a set of standard acceptable risk criterion was codified and public safety risk is now a shared responsibility of NASA Center Directors and Program Managers.

Sharing Risk Codes and Expertise

Based on the clarified requirements and responsibilities outlined in the NASA procedural requirement, the committee's tasks for fiscal 2007 will include exploring and developing a mechanism for Centers to share risk codes and expertise in an attempt to standardize processes. A trial run of this concept was successfully executed at the Wallops Flight Facility where risk analysts from Kennedy Space Center and the 45th Space Wing performed the required assessments for distant focusing overpressure and toxics risk for the Air Force Research Laboratory's TacSat-2 mission.

Determining Training Needs

Training needs and requirements for code developers and operators will also be evaluated. The committee will determine and evaluate appropriate NASA level requirements for code configuration management and verification and validation and attempt to standardize these requirements and interpretations across all NASA centers. Shared public safety responsibility for NASA missions launched from Department of Defense ranges makes understanding and accommodating other agency needs and efforts with respect to risk modeling a must for successful completion of committee goals.

With much work on the horizon, the NASA Range Safety Analysis Tools Development Committee looks forward to a successful and productive 2007.

Support to Program Operations

Self-Service Management Tool (SSMT)

The *NASA Safety Manual*, NPR 8715.3, specifically states Agency safety priorities for the public, astronauts and pilots, the NASA work force, and high value equipment and property. NPR 8715.5, *NASA Range Safety Program*, describes the roles and responsibilities, requirements, and procedures for protecting the safety of the public, the workforce, and property during range operations associated with flight. To meet these procedural requirements, the risk posed to human life and property must be evaluated as either acceptable or unacceptable.

If management determines the risk is too high, then mitigations must be devised to lower the assessed risk to an acceptable level. Risk mitigation actions—based on debris, toxic, and far-field risk modeling results—must be implemented, monitored, and executed to contain or mitigate the hazard to a level acceptable for operations to continue.

In January 2006, Mr. James Kennedy signed a Center Director's Communication regarding the importance of the SSMT database. This communication is included below:

CENTER DIRECTOR'S COMMUNICATION

CD COMM #2006-01

January 9, 2006

AA

TO: All Kennedy Space Center (KSC) Civil Service and Contractor Employees

SUBJECT: KSC Launch/Landing Risk Assessments

In keeping with NASA core values, personnel safety continues to be a high priority not only during day-to-day activities but also during spaceflight operations. What you may not know is that for every Shuttle and Air Force launch or landing, our KSC Range Safety team is assessing personnel risks in the effort to ensure these operations are performed safely. Along with vehicle readiness, these assessments are an important factor in determining whether an operation can proceed. By necessity, these assessments need to be as accurate as we can make them. One of the main factors affecting accuracy is knowing where our personnel are during these activities.

Our KSC Range Safety team has been working on a simple way to collect this information, and it involves the use of a database called Self-Service Management Tool (SSMT). This database allows you to identify your normal work locations/times and now has the ability to capture where you will be located for upcoming launch/landing events for those of you who move from one location to another when supporting these activities.

In the coming days, you will see an announcement in the "KSC Daily News," where the team has embedded a direct link to the SSMT database input wizard. This wizard is straightforward and should take no more than a few minutes to complete. However, if you should have any difficulties utilizing the database, there will be contact information within the announcement to assist you. There also will be a [Spaceport News](#) article providing more information and detailing the importance and relevance of this effort.

In summary, I fully endorse this initiative and expect all KSC personnel to provide their information into SSMT. I understand this is yet another task added to your busy schedules; however, this information is essential in our effort to protect you—our most valuable resource.

To start right now, you can access the following link: [SSMT Launch Activity Wizard](#).

Original Signed by
James W. Kennedy

Risk Assessments

NASA Range Safety assesses the risk to the public and personnel for safe operations on Kennedy Space Center using computer models to produce risk assessments. These assessments are considered for clearance to proceed with a launch and/or landing operation. The assessments must be as accurate as possible to reduce the need to make conservative decisions. Visitor numbers and locations are typically provided by Kennedy Space Center External Relations for popular viewing locations such as the Kennedy Space Center Visitor's Center, NASA Causeway and the Launch Complex 39 Press Site.

One of the main factors for assessment accuracy is the location of personnel; specifically, numbers of personnel, categories of personnel (Mission Essential, Operations, or Non-Essential), when personnel work, and where personnel work during launch and landing time (buildings, rooms, floors, or outside areas).

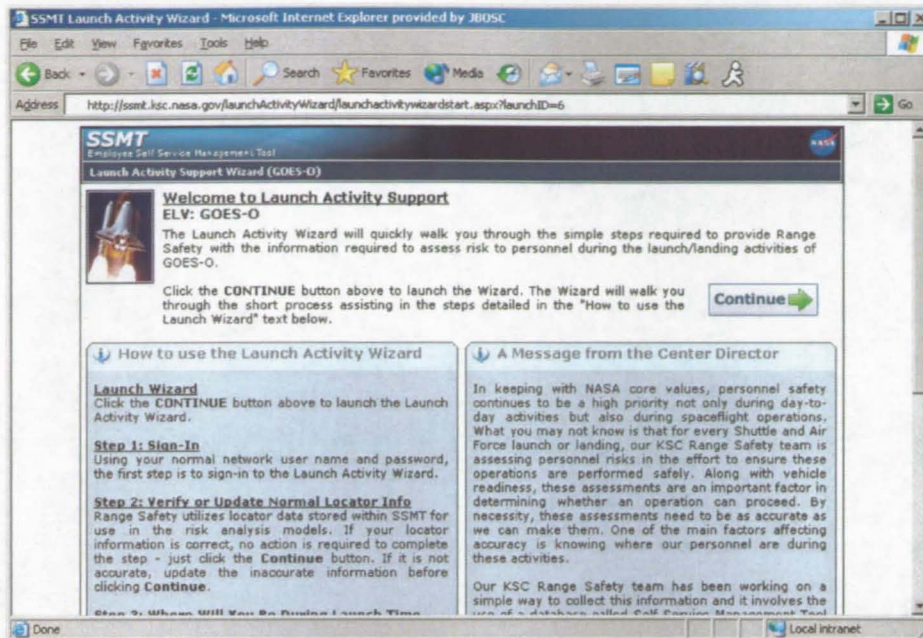
Self-Service Management Tool

The Self-Service Management Tool is one of the prime information sources Range Safety analysts use to collect information to assess risk to Kennedy Space Center personnel and property. The program has been in use for some time for a number of other activities.

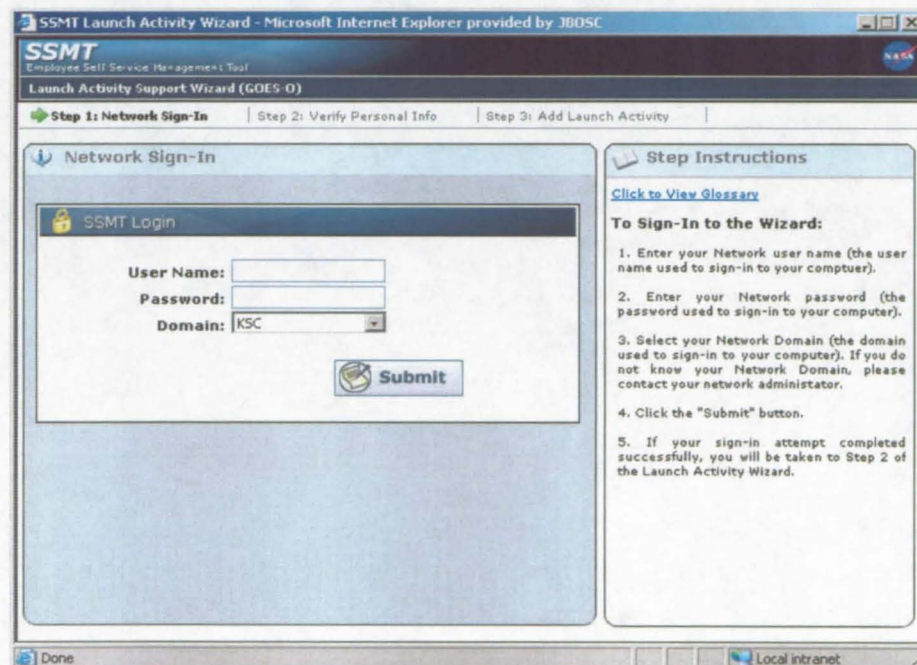
The current capability captures personnel locations and shift information for normal duty hours. NASA Range Safety saw great potential in using this system since personnel were familiar with it and it captures information down to the room level. NASA Range Safety sponsored adding a launch/landing module to the system database so information could be gathered for each launch for all personnel.....not just those supporting a particular launch.

Using the Self-Service Management Tool

To access the tool database system, visit <http://ssmt.ksc.nasa.gov/launchactivitywizard>. From the Kennedy Space Center internal home page, a link is provided that will take you to the Launch Activity Support Wizard shown below. Clicking the Continue button takes you to the next screen.



The screen at right allows you to sign in to the Launch Activity Support Wizard using your normal log-on information. Clicking the Submit button takes you to the Normal Locator Information screen.



At the Your Normal Locator Information screen, you can view and modify your normal locator information. Clicking the Continue button takes you to the Step 3: Add Launch Activity screen.

SSMT Launch Activity Wizard - Microsoft Internet Explorer provided by JBOSC

SSMT
Employee Self Service Management Tool

Launch Activity Support Wizard (GOES-O)

User: Michael Helmick

Step 1: Network Sign-In

Step 2: Verify Personal Info

Step 3: Add Launch Activity

Verify or Modify Your Normal Locator Information

Working Phone: (321)867-3241

Mail Code: SGS-657

Alt. Work Phone:

Cell Phone: (321)759-8612

Fax: (321)867-3236

Pager:

Display Cell: ☒

Display Pager: ☐

Department: SGS-8081

Facility: BASE OPERATIONS BLDG.

Room: 21405

Seating: Desk

Work Days: ☒ Mon ☒ Tue ☒ Wed ☒ Thu ☒ Fri ☐ Sat ☐ Sun

Start Time: 08 HH 00 MIN

End Time: 17 HH 00 MIN

Continue

Step Instructions

[Click to View Glossary](#)

To Verify/Update Locator Info:

1. If your information is correct, no action is required. Simply click the **CONTINUE** button.
2. NASA Civil Servants may not change their department (*).
3. If you do not remember your exact department, facility and room, suggested matches are shown as you type in the field. Once the desired value is displayed, click to copy it into the field.
5. If can't find your department or room please click on "Item does not exist. Click to Add". Clicking this will allow you to correct your information without waiting for the value to be added.
6. Click **CONTINUE** when you have finished updating your normal locator information.

Local intranet

Step 3: Add Launch Activity, shown in the screen to the right, allows you to enter information for your location during a specific launch activity. If your location is the same as your normal locator information, just check the Use Normal Locator Information box and continue and click Submit.

This step also allows you to designate your launch status (Mission Essential, Operations, Non-Essential) and specific location for the launch activity.

SSMT Launch Activity Wizard - Microsoft Internet Explorer provided by JBOSC

SSMT Employee Self Service Management Tool

Launch Activity Support Wizard (GOES-O)

User: Michael Helmick

Step 1: Network Sign-In Step 2: Verify Personal Info Step 3: Add Launch Activity

Where Will You Be During Launch Time (T-0)?

Launch Activity: GOES-O

☐ Use Normal Locator Information

Mission Essential: ☒ Non-Essential ☐ Mission Essential ☐ Ops Personnel

Location: ☒ KSC/CCAFS ☐ Not at KSC/CCAFS

Facility:

Room:

Go Back Submit

Step Instructions

[Click to View Glossary](#)

1. If you will be sitting at the same location during launch as a normal work day, click the "Use Normal Locator Information".
2. Indicate whether you are considered non-essential, mission essential or operational personnel. For definitions of each choice, see the Glossary. If you have any question regarding your classification, contact your supervisor.
3. Select your Facility by typing into the Facility field. A list of possible matches are shown as you type in the field.
4. Select your Room by typing into the Room field. A list of possible matches are shown as you type in the field.
5. Click **CONTINUE** to proceed to the next step in the Wizard.

Done Local intranet

The Step 4: Add Landing Activity screen allows you to enter the same type of information that you entered for launch. Clicking Submit takes you to the final screen.

SSMT Launch Activity Wizard - Microsoft Internet Explorer provided by JBDSC

SSMT
Employee Self Service Management Tool

Launch Activity Support Wizard (STS-121 Launch Support)

User: Michael Helmick

Step 1: Network Sign-In Step 2: Verify Personal Info Step 3: Add Launch Activity **Step 4: Add Landing Activity**

Where Will You Be During Landing?

Landing Activity: STS-121 Landing Support

☐ Use the Same Information as Launch
☐ Use Normal Locator Information

Mission Essential: ☒ Non-Essential ☐ Mission Essential ☐ Ops Personnel

Location: ☒ KSC/CCAFS ☐ Not at KSC/CCAFS

Facility:

Room:

[Click to View Glossary](#)

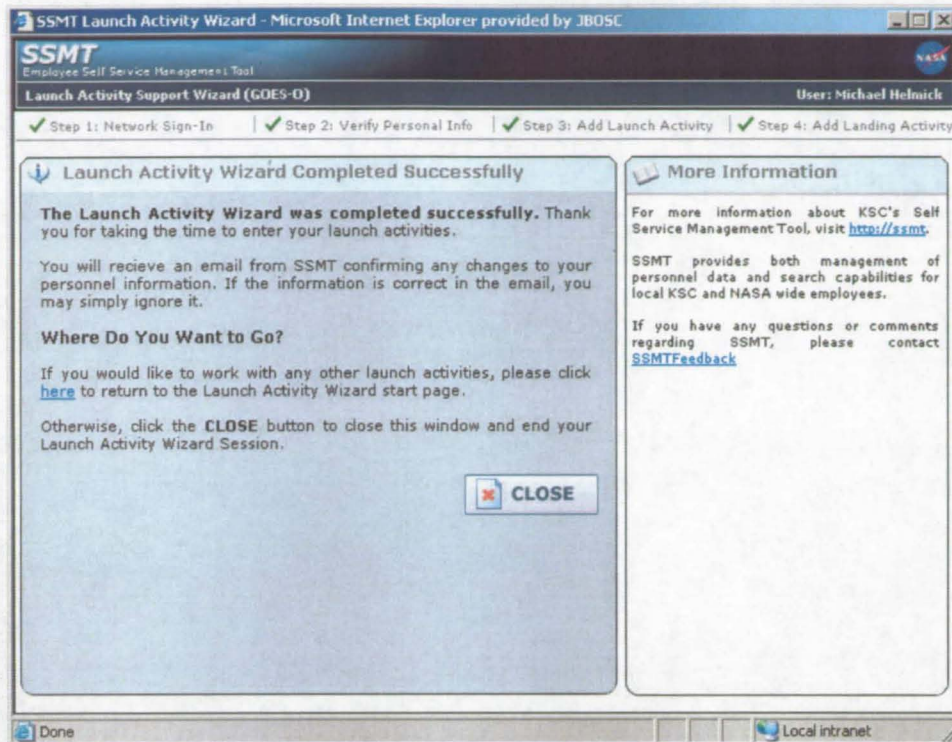
Filling out the Landing Activity is identical to the process for Launch Activity.

1. If your location and involvement is identical for landing and launch, check the "Use the Same Information as Launch" checkbox.
2. Indicate whether you are considered non-essential, mission essential or operational personnel. For definitions of each choice, see the Glossary. If you have any question regarding your classification, contact your supervisor.
3. Select your Facility by typing into the Facility field. A list of possible matches are shown as you type in the field.
4. Select your Room by typing into the Room field. A list of possible matches are shown as you type in the field.
5. Click **CONTINUE** to proceed to the next step in the Wizard.

[Go Back](#) [Submit](#)

Done Local Intranet

The final screen lets you know if you completed entering your information appropriately and allows you to migrate to others areas of the system.



The Importance of Self-Service Management Tool Data

Along with the type of launch vehicle, Range Safety analysts use this information about personnel and other numerous parameters, such as winds, building structures, and failure rates, to determine risk estimates.

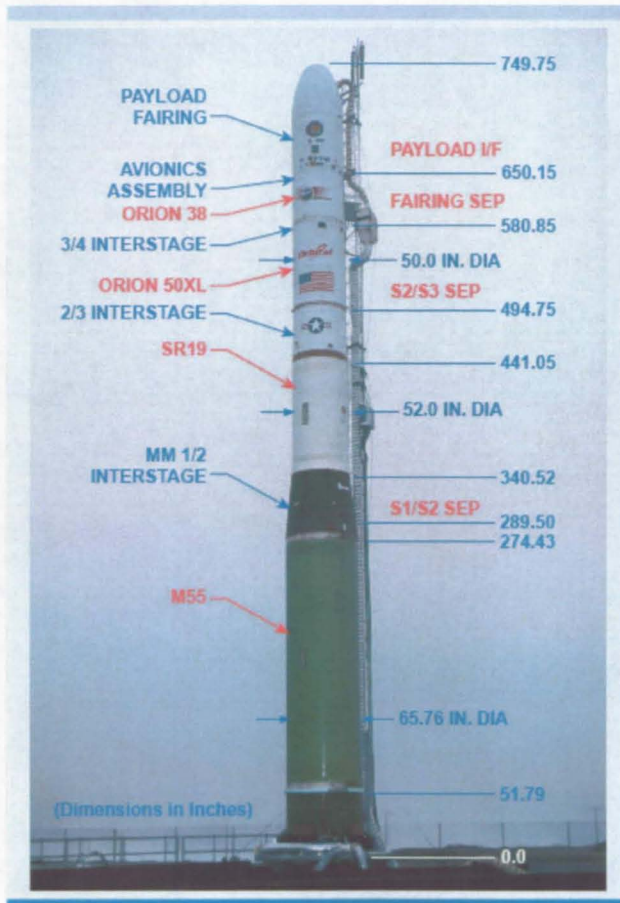
It is critical that Kennedy Space Center personnel update their information in the Self-Service Management Tool database at least quarterly to ensure day-to-day information is correct. Personnel should also update the information for each launch and landing event for Shuttle and expendable launch vehicle activities on Cape Canaveral Air Force Station. Kennedy Space Center Range Safety ensures up-to-date launch and landing manifest selections are available in the Self-Service Management Tool program.

The continued use of the Self-Service Management Tool program greatly enhances the protection of Kennedy Space Center's most valued resource—its people.

Support of Toxics and Distant Focus Overpressure Evaluations

TacSat-2: Kennedy Space Center Range Safety Support of Toxics and Distant Focus Overpressure Evaluations

TacSat-2, a small technology mission sponsored by the [Air Force Research Laboratory](#), was launched aboard an Orbital Minotaur 1 vehicle from the Wallops Flight Facility in December 2006. The [Orbital Suborbital Program Minotaur 1](#) launch vehicle consisted of an M-55 (51,514 pounds) and SR-19 (13,740 pounds) first and second stage taken from the Minuteman-2 as shown in the picture below. Upper stages consisted of an Orion 50XL motor and Orion-38 motor, both of Pegasus heritage.



Although launch vehicles of significant size have been launched from Wallops Flight Facility in the past, this is the first time Wallops has performed a detailed analysis of toxic and overpressure hazards. A Tier 1, or screening evaluation, of the TacSat-2 mission performed by the 45th Space Wing revealed an in-depth toxics and distant focusing overpressure analysis was required.

The close proximity of the Minotaur 1 launch vehicle (over 65,000 pounds of solid rocket propellant) to the off-base public drove the need for more detailed analysis. Based on the data requirements, first time evaluation of these hazards required a significant effort. The TacSat-2 mission was required to meet the acceptable risk criteria contained in [NASA Procedural Requirement 8715.5, Range Safety Program](#).

Kennedy Space Center Range Safety volunteered to assist Wallops in evaluating the public and workforce risk due to toxics and distant focusing overpressure resulting from the TacSat-2 mission.

Kennedy Space Center Range Safety has gained a significant amount of experience in evaluating these hazards at the Eastern Range and has assisted Wallops in the development, coordination, and real-time support of toxic and distant focusing overpressure risk evaluations. The 45th Space Wing and ACTA Inc provided significant support to this effort.

Kennedy Space Center Range Safety assumed the lead on coordinating contractor and 45th Space Wing support, tracking task progress, leading technical discussions, and

facilitating weekly telecons. Development of off-base and on-base population databases, terrain and structural databases, yield histograms, and historical meteorological files required to support a Wallops Flight Facility hazard analysis were completed.

Kennedy Space Center Range Safety also completed a distant focusing overpressure availability study and coordinated with the 45th Space Wing and ACTA to complete a toxics availability study. These availability studies aided the assessment team in determining the need for additional development of input assumptions and allowed decision makers to gain an understanding of the probability of potential launch holds.

Launch day operations support by Kennedy Space Center Range Safety consisted of running and reporting real-time distant focusing overpressure risk, coordinating with the 45th Space Wing to provide real-time toxic modeling support, and coordinating with ACTA to provide meteorological and technical support. On 16 December at 0700, TacSat-2 was successfully launched from the Mid-Atlantic Regional Spaceport on the southern tip of the Wallops Flight Facility with no concerns with respect to toxic or distant focusing overpressure risk mostly due to north westerly winds.

Emerging Technology

Space-Based Telemetry And Range Safety 2006

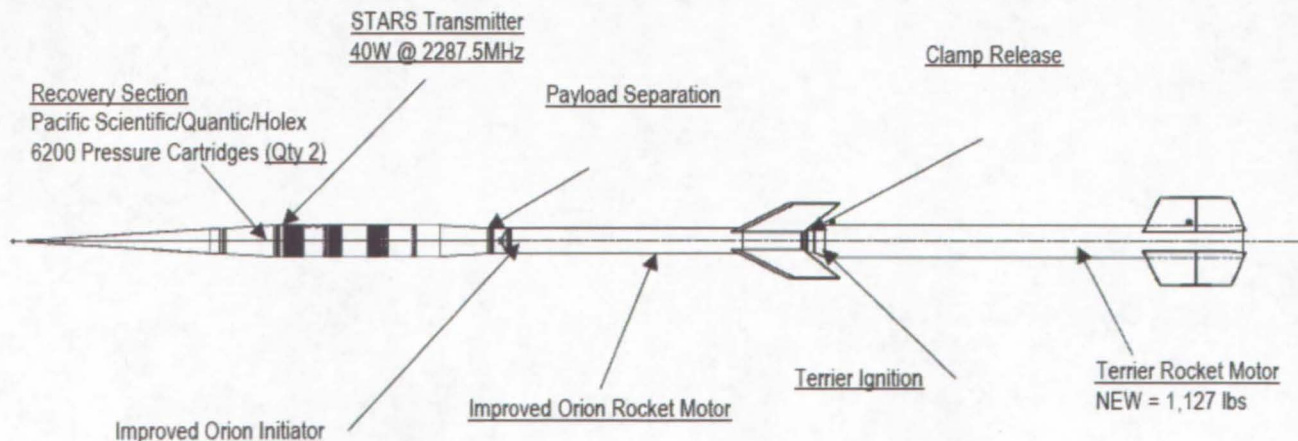
Space-based range demonstration and certification, formerly called *space-based telemetry and range safety (STARS)*, is a multicenter NASA proof-of-concept project to determine if space-based communications can support Range Safety functions (tracking data and flight termination signals) while also providing broadband Range User data (voice, video, and vehicle/payload data).

Space-based range demonstration and certification is made up of the Range Safety and the Range User systems. The Range Safety system sends tracking data from the vehicle to the ground and receives flight termination commands from the ground. The Range User system sends high-data-rate vehicle telemetry from the vehicle to the ground. Both systems use NASA's Tracking and Data Relay Satellite System.

Rocket Space-Based Range Demonstration and Certification System Test

A successful test of the Range Safety system was held at Wallops Flight Facility on December 20, 2005 on a two-stage, Terrier-Orion, spin-stabilized sounding rocket. A diagram of the rocket is shown below. A photograph of the launch is on the next page.

The first-stage Terrier MK 70 booster was 18 inches in diameter, 155 inches long, and weighed 2177 pounds before ignition. The second stage Improved-Orion sustainer was 14 inches in diameter, 105 inches long, and weighed 965 pounds before ignition. The recoverable payload section was 165 inches long and weighed 526 pounds.



During the sounding rocket launch and flight, the space-based range demonstration and certification Range Safety system generally behaved very well on the highly dynamic, rapidly spinning (~5 hertz) sounding rocket, receiving data from the GPS constellation and maintaining links with two Tracking and Data Relay Satellite System satellites simultaneously during the entire 10 minute flight.

The payload section deployed a parachute and landed in the Atlantic Ocean about 90 miles downrange from the launch site. Its maximum altitude was about 115 miles, and its maximum speed was in excess of Mach 5. The acceleration just after lift-off was about 20 g's.

More than 99 percent of all forward commands were successfully received and processed, and more than 95 percent of all return frames were successfully received and processed at the control center at Wallops Flight Facility.

The latency for a single command to travel over land lines to White Sands Complex and then to the vehicle via a tracking and relay data satellite, and to be processed onboard and received back at the control center at Wallops Flight Facility—again via tracking and relay data satellite and land lines—was between 1.0 and 1.1 seconds, which should meet the Range Safety requirements. The forward link margins for Tracking and Relay Satellite-10

(designated *TDE* and located at 41° W Longitude) were between 11-12 ± 2 dB and between 9-10 dB ± 1.5 dB for Tracking and Relay Satellite-4 (designated *TDS* and located at 46° W Longitude). The Range Safety system hardware was recovered dry, but one of the antennas was damaged while the payload was being recovered at sea.



The [attached video](#) shows the launch, re-entry, and recovery of the rocket.

F15 Space-Based Range Demonstration and Certification System Tests

A set of test flights on an F15 at Dryden Flight Research Center is currently underway. The primary goal for the Range User is to test a Ku-band, phased-array antenna with a data rate of 5 megabytes per second. The antenna is electronically steerable in elevation and mechanically steerable in azimuth and is mounted on top of the F15 behind the cockpit. Preliminary analysis indicates that the system performed well and additional analysis is underway.

The Range Safety system will test the ability to maintain lock with two Tracking and Data Relay Satellite System satellites simultaneously on a highly dynamic aircraft simulating an out-of-control launch vehicle and hand-off between the launch head and the Tracking and Data Relay Satellite System. Additional measurements will be made of the link margin and data latency.

Autonomous Flight Safety System – Phase III

The [autonomous flight safety system](#) is a joint Kennedy Space Center and Wallops Flight Facility project currently in its third phase of development. The autonomous flight safety system is an independent and autonomous flight termination subsystem intended for expendable launch vehicles. It uses tracking and attitude data from an onboard GPS and inertial measurement unit sensors and configurable rule-based algorithms to make flight termination decisions.

The objectives of the autonomous flight safety system are as follows:

- Increase capabilities by allowing launches from locations that do not have existing range safety infrastructure
- Reduce costs by eliminating some downrange tracking and communications assets
- Increase safety by reducing the reaction time for flight termination decisions

Sounding Rocket Flight Test

The autonomous flight safety system flew on the Terrier Improved-Orion, two-stage sounding rocket shown at the right at White Sands Missile Range on April 5, 2006. A single-chassis, dual-processor, dual-GPS system was used.

The primary purpose of this flight was to demonstrate the key elements of the autonomous flight safety system concept of operations pertaining to pre-launch set-up (loading and verifying the application and configuration files), bench testing, vehicle integration, in-vehicle end-to-end testing, count-down system verification procedures, and flight operations. A secondary purpose was to gather lessons learned which could be codified into the Autonomous Flight Safety System System Level Requirements document currently under revision.



The test incorporated redundant GPS sensors and used two independently programmed processors. One was loaded with a nominal trajectory and the other programmed with artificial rules under which the nominal flight would violate safety parameters and provoke termination commands. The autonomous flight safety system was not connected to actual explosives. The system functioned and reacted correctly during the entire flight from launch to parachute deployment.

SpaceX Falcon 1 Orbital Flight at Kwajalein Reagan Test Site

The autonomous flight safety system was scheduled to fly on the next SpaceX Falcon I launch in January 2007 from the Reagan Test Site at Kwajalein. The Falcon I, shown at right, is a two-stage, liquid oxygen and rocket grade kerosene powered launch vehicle designed to achieve substantial improvements in reliability and cost and to deliver 480 kilograms (1058 pounds) to an orbit of 200 kilometers at 28.5° inclination. The first stage is almost entirely reusable and returns via parachute to a water landing. Lift-off weight for the standard Falcon I is approximately 27,000 kilograms (60,000 pounds), length is about 22 meters (70 feet) and diameter is 1.67 meters (5.5 feet).

The autonomous flight safety system will interface with the [low cost TDRSS transmitter](#) to demonstrate space-based range concepts. The low cost TDRSS transmitter will transmit autonomous flight safety system GPS metric tracking and flight termination data to NASA's Tracking Data and Relay Satellite System. The Tracking Data and Relay Satellite System will relay the autonomous flight safety system data to White Sands Missile Range where it can then be transmitted to Wallops Flight Facility, Kennedy Space Center, and Kwajalein for analysis.

The primary objectives for the autonomous flight safety system during this launch opportunity are:

- To test as many elements of the Autonomous Flight Safety System Concept of Operations as feasible within a true expendable launch vehicle integration and launch operations environment
- To gain expendable launch vehicle test, integration, countdown, and flight experience time on specific autonomous flight safety system hardware configuration, including the first flight test of the command logic switching and interlock circuit board
- To gain expendable launch vehicle test, integration, countdown, and flight experience time on specific autonomous flight safety system software configuration items, including the configurable flight algorithm mission rule constructs, cross-sensor qualification algorithms, staging event detection algorithms, and the command logic switching and interlock circuit board voting firmware

The autonomous flight safety system hardware will be part of the payload and will not be recovered.



Enhanced Flight Termination System Program

The objective of the enhanced flight termination system program is to develop the next generation flight termination system for the Department of Defense and NASA ranges. The program addresses robust command links for flight termination, including message formats, modulation methods, and encryption.

Previous Status

The Range Safety Group of the Range Commanders Council initiated a study task and ultimately selected continuous phase frequency shift keying as the modulation scheme, a 64-bit triple data encryption standard for security, and the layout of the 64-bit message for the new system. The Air Force Flight Test Center then let a contract to build prototype enhanced flight termination receiver decoders and an encoder for the ground transmitter. The receiver decoder and encoder units successfully demonstrated that the enhanced flight termination system would function in flight and in an operational setting.

The Central Test and Evaluation Investment Program is funding the development of the flight termination receiver decoders, encoders, monitors, and encryption units for different range applications, such as uninhabited aerial vehicles, space launch vehicles, and missiles. In August 2004, two contracts to develop the enhanced flight termination receiver decoder engineering development units were awarded to L-3 Cincinnati Electronics and Herley Industries. In August 2005, a contract to develop the ground systems (enhanced flight termination system encoder, monitor, and encryption unit) was awarded to L-3 Cincinnati Electronics.

Current Accomplishments

Milestones accomplished this year are described below.

- In September and November 2005 and February 2006, system, preliminary, and critical design reviews on the development of the ground systems were held with L-3 Cincinnati Electronics.
- In February 2006, L-3 Cincinnati Electronics successfully held a test readiness review to initiate the qualification and acceptance testing of the flight termination receiver decoder. Qualification testing is expected to be completed in November 2006.
- In early August 2006, three of the units successfully passed acceptance testing at L-3 Cincinnati Electronics.
- In late August 2006, the ground systems (encoder, monitor, encryption unit) were successfully tested at L-3 Cincinnati Electronics and delivered to the Air Force Flight Test Center.

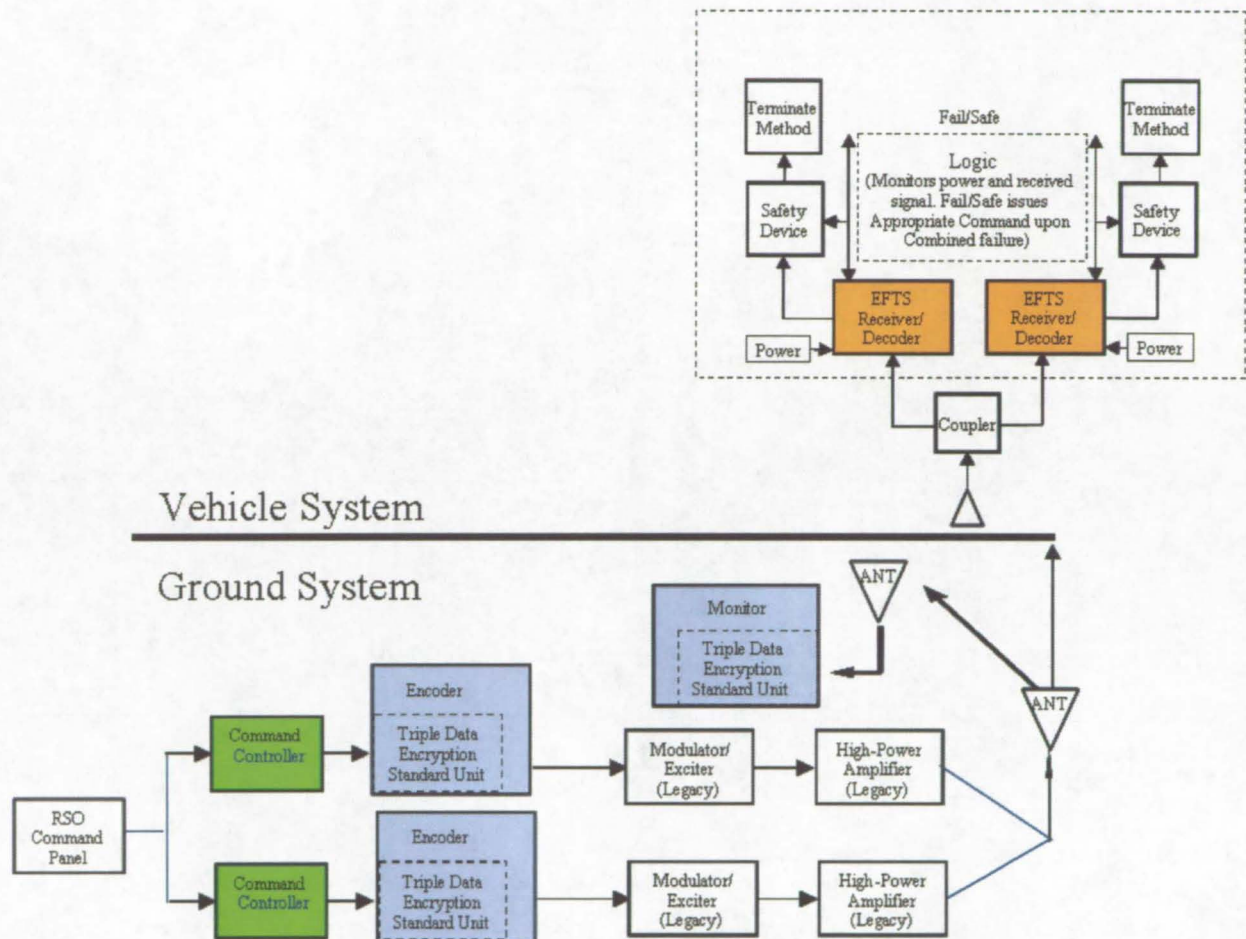
Future Plans

The enhanced flight termination system program plans to test the operational hardware on an advanced mid-range air-to-air missile at Eglin Air Force Base, Florida in early 2007 using a qualified flight termination receiver and the ground equipment currently under development. This will be the first of several flight tests in 2007 involving the new enhanced flight termination system components.

The final phase of the program provides the mechanism to field ground systems for production and deployment on all Department of Defense and NASA ranges. This part of the program is expected to begin in the 2007 timeframe.

Enhanced Flight Termination System Architecture

The enhanced flight termination system architecture consists of the vehicle and ground systems shown in the diagram below. The enhanced flight termination system was designed so that upon the completion and qualification of all units for both airborne and ground systems, implementation with existing architecture would minimally impact the ranges.



On the airborne side, the enhanced flight termination system uses existing components and systems, where the only new addition would be the new enhanced flight termination system command receiver/decoder. Legacy antennas, couplers, logic units, safety devices, and ordnance will be used along with the new command receiver/decoders and ground equipment.

The ground systems architecture will change somewhat, but the impacts will not be severe. Ranges will have to purchase the new enhanced flight termination system ground equipment (encoders, monitors, and triple data encryption units) and each range can develop the unencrypted 64-bit enhanced flight termination system command frame (command controller) based on its own culture. The ground system will also implement

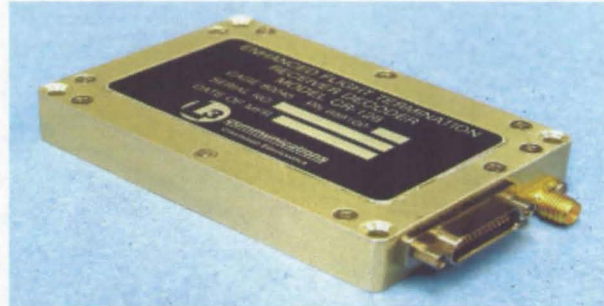
existing technology and equipment including Range Safety Officer command panels, modulators/excitors, high power amplifiers, and command transmitters.

Enhanced Flight Termination System Equipment

Four of the major components of the enhanced flight termination system—enhanced flight termination receiver, triple data encryption unit, encoder, and monitor—are described below.

Enhanced Flight Termination Receiver

The receiver takes the encrypted messages sent from the command transmitter system (modulator, exciter, power amplifier) and decrypts them into useable commands.



Triple Data Encryption Unit



The triple data encryption unit is embedded within the encoders and encrypts the messages using the Triple Data Encryption Standard. A triple data encryption unit is embedded within each monitor for decryption of the enhanced flight termination system message for analysis.

Encoder

The encoder takes the encrypted message from the triple data encryption unit and adds a certain amount of frame synchronization and parity bits for forward error correction before sending the final message to the Legacy excitors.



Monitor

The monitor is used as an analysis tool for Range Safety by providing an independent verification process for the transmitted enhanced flight termination system signal. The command transmitter system sends the final, encrypted enhanced flight termination system message to the receiver and to the monitor.



After 2006, the enhanced flight termination system program is one step closer to bringing a new, qualified, improved system to ranges and range users. As this program nears completion of qualification testing on all components involved, Range Safety has set its sights toward the operational and flight testing that will take place throughout 2007.

Multiple milestones have to be met as the program continues to get closer to bringing a new system currently under development into operational status. Range Safety will continue to work with the enhanced flight termination system program and support the mission of providing a new advanced method of flight termination that will be low cost and low impact to ranges and range users, while providing a reliable system that will help ensure public safety during launch operations.

Joint Advanced Range Safety System

The joint advanced range safety system is a collaborative effort between Dryden Flight Research Center and the Air Force Flight Test Center at Edwards Air Force Base. The effort is to develop a state-of-the-art mission planning, risk analysis, and risk management tool for Range Safety. The Range Safety organizations from all Major Range and Test Facility Bases are being asked to support the development, testing, and operation of uninhabited aerial vehicles and reusable launch vehicles. It is the vision of joint advanced range safety system to provide range safety support for these missions.

Primary System Elements

The joint advanced range safety system consists of two primary elements: a mission analysis software tool and the real-time operations tool. The mission analysis software tool will quantify the range safety risk for a given flight path and its associated vehicle parameters using a computerized method. This method will streamline the range safety analysis process by providing a consistent, high fidelity solution in less time than required by present methods of analysis.

Additionally, the real-time operations tool will provide the Range Safety Officer with near real-time assessment of the range safety risks during flight. This capability has many possible applications for the uninhabited aerial vehicle or reusable launch vehicle operator, including the following:

- Assessment of uninhabited aerial vehicles overflight of populated areas
- Allowing extended flight of an anomalous vehicle
- Recovery of an off-nominal vehicle at an alternate landing site
- Selection of an alternate flight or entry path

Status

The joint advanced range safety system mission analysis software tool is nearing operational status and is expected to be available for government use in 2007. The mission analysis software tool is undergoing an independent software assurance assessment from NASA's Independent Verification and Validation Facility in West Virginia. Work on the joint advanced range safety system real-time operations tool has not begun due to lack of funding.

Joint Advanced Range Safety System Team

The Joint Advanced Range Safety System Team would like to welcome two new members, the United States Air Force's 30th and 45th Space Wings. The Eastern and Western Launch Ranges have contributed to the development of joint advanced range safety system modules that focus on the Range Safety analysis of space launch vehicles. Welcome aboard.

The Joint Advanced Range Safety System Team would also like to recognize the contributions of Johnson Space Center, Kennedy Space Center, and Wallops Flight Facility for providing valuable input during their initial evaluation of the tool's capabilities.

Eastern Range Instrumentation Update

The Eastern Range is the launch head at Cape Canaveral Air Force Station, which also supports Kennedy Space Center launches. Range Management activities are hosted at Patrick Air Force Base under the command of the 45th Space Wing. Downrange sites include Jonathan Dickinson Missile Tracking Annex and Antigua, Argentinia, and Ascension stations. In the context of space launch operations, the Eastern Range includes all of the surrounding air, sea, and land space that is within the range of any particular launch vehicle. The Eastern Range is not part of NASA but supports NASA activities.

Primary Objective of the Eastern Range

The primary objective of the Eastern Range is to provide for the safety of the public during launch operations. The activities and resources to ensure safety of flight include range instrumentation, infrastructure, and scheduling required to support and ensure that space and ballistic launches and other operations are appropriately supported.

The Eastern Range Range Safety Program uses instrumentation that is comprised of legacy and state-of-the-art technologies to ensure launch mission safety, launch area safety, and launch complex safety. Range instrumentation is primarily at the Florida locations of Cape Canaveral Air Force Station (missile row shown in the picture at right) and Patrick Air Force Base. The Eastern Range also uses instrumentation from other Department of Defense and NASA agencies to accomplish its mission.



Information Provided by Instrumentation



During launch operations, Eastern Range instrumentation provides vehicle positioning information from radar, vehicle telemetry, and optic tracking systems. Additionally, telemetry also provides vehicle health and status through its data stream. This range safety critical data is shipped via the range communication CORE network to the range safety display strings located in the Range Operations Control Center at Cape Canaveral Air Station. The Range Operations Control Center is shown to the left.

Range Safety Strings

The current range safety strings (the equipment that data flows through) are designated as Flight Operations Version One (FOV1) and located at the Range Operations Control Center. The FOV1 system provides an Eastern Range range safety function and monitors launch vehicle performance. FOV1 consists of two independent systems: FOV1-A and FOV1-B. The systems acquire and process instrumentation data from the Eastern Range, NASA, and off-range sites through redundant network paths. Using the instrumentation data, these systems generate flight path and predicted impact point displays similar to the one shown below.

Using these displays, the Mission Flight Control Officer determines the risk based on pre-defined mission rules and, if required, destroys any vehicle that violates those rules. The 45th Space Wing Safety Office personnel devise these mission rules to ensure public safety from any errant launch vehicle incident. This is the primary Eastern Range function.

FOV1 is constantly going through upgrade and development efforts. The current follow-on development effort is ongoing and is expected



to be completed in early 2007.

Post-Detect Telemetry System

The premier Eastern Range launch vehicle telemetry acquisition system is the post-detect telemetry system. This system provides transport of digital post-detect telemetry data from Eastern Range telemetry sites via the Network CORE System Wide Area Network Interface Units and the microwave and commercial circuits from Jonathan Dickinson Missile Tracking Annex.



Post-detect telemetry system sites include Tel-4 at Kennedy Space Center (shown at left), Jonathan Dickinson Missile Tracking Annex, Antigua, and Ascension. The post-detect telemetry data is transported to the launch customer facilities and the Range Operations Control Center (FOV1) for range safety purposes.

In 2006, the developer updated post-detect telemetry system software to Version 3.1 to provide resolution of deficiency reports generated before post-detect telemetry system initial acceptance.

INTEL SATCOM

The INTELSAT SATCOM System now consists of two separate SATCOM strings: A Side and B Side. SATCOM A, the second phase of the post-detect telemetry system project, was modified in 2006 and implemented at the Eastern Range with the post-detect telemetry system bandwidth, polarization, and modulation format. This new digital communication transport service is the Eastern Range secondary telemetry and transport management system circuit transport carrier from the downrange stations of Antigua and Ascension to the Range Operations Control Center. The control center antenna is shown to the right.



Wide Area Network Interface Units System

The Network CORE Wide Area Network Interface Units system is the major transport mechanism to Range Safety and telemetry data end users. The CORE provides the communication backbone at Cape Canaveral Air Force Station. The CORE consists of four rings, two OC-48 (red 2488 megabits per second) and two OC-12 (green 622 megabits per second). The communication link to NASA is through the Launch Control Center. The primary nodes are the Range Operations Control Center, XY Facility, Southwest Terminal Building, and the East Terminal Building.

Central Telemetry Processing System

The Central Telemetry Processing System is used for the processing, distribution, and display of Range Safety telemetry data during the powered flight portion of Eastern Range launches. Post-detect data streams into the Central Telemetry Processing System where it undergoes frame synchronization and decommutation. The resulting telemetry parameters are used to generate 4.8 kilobits per second range safety outputs. This 4.8 kilobits per second data is forwarded to the FOV1 system for further processing and display.

Replacing the Cyber 860 Mainframe Computers

Many pre- and post-launch analysis products are produced at the Cape Central Computer Complex. For over 20 years, the Eastern Range has depended on Cyber 860 mainframe computers at the Central Computer Complex to produce launch critical instrumentation analysis and Range Safety flight analysis. These computers and the code that resides in them are outdated in that the hardware is very costly to maintain and software problems are too difficult to fix. Two projects are in progress to replace the 860 Cyber mainframe computers.

Launch Analysis Production System. The Launch Analysis Production System project is slated to replace Cyber 860 instrumentation analysis. The project is translating instrumentation analysis computer programs originally written in CDC Cyber FORTRAN to C++ programs that can be hosted on a standard personal computer with a Windows operating system. The project started in April 2005 and is presently scheduled to have the instrumentation analysis programs functioning by mid-2008. Most of the Launch Area Production System hardware has been installed and initial testing is underway.

Safety Hazards Analysis and Risk Processing. The Safety Hazards Analysis and Risk Processing project is slated to replace Cyber 860 flight analysis automation. The project is re-hosting the CDC Cyber FORTRAN flight analysis programs primarily using MATLAB. This system will have open system architecture to allow incorporation of innovations in processor speed and storage capacity without major redevelopment. New commercial off-the-shelf software can be incorporated as "add-on" tools. The architecture will also accommodate the latest built-in analytical tools.

Safety Hazards Analysis and Risk Processing is a two-phased project. Phase 1 will provide the host computer, backup storage, version control tools, and an initial suite of flight analysis software modules. Phase 1 software modules will enable flight analysts to process range user and weather data to produce range safety display backgrounds and range safety risk-based products for launch day support.

Successful completion of Phase 1 will eliminate 45th Space Wing reliance on the Cyber 860 mainframes to produce flight analysis launch support products. Phase 1 is on schedule to be completed by October 2007. Phase 2 will provide flight analysis enhancements that were not previously possible due to Cyber 860 limitations and organic software maintenance capability.

Automated Range Surveillance using Radio Interferometry

As NASA's primary launch operations center, Kennedy Space Center is very interested in new technologies that will lower Range Safety's operations and maintenance costs while increasing reliability. Kennedy Space Center's [Advanced Systems Division](#) has taken advantage of NASA's [Small Business Innovation Research](#) program to help develop advanced Range Safety technologies by successfully obtaining awards for contracts and managing the Small Business Innovation Research subtopic that solicits technologies for automated collection and transfer of range surveillance and intrusion data.

Range surveillance is a primary focus of launch range safety and often a cost and schedule driver. Because of the difficulty of verifying a cleared range, launch delays are common and will increase as spaceports are developed in new areas. To address this issue, a 2005 Small Business Innovation Research Phase I contract was awarded to Soneticom, Inc. to develop a system for automated range surveillance using radio interferometry.

Proposed Automated System

The proposed automated range surveillance system will use a small network of remote sensors to perform radio interferometry and time difference of arrival techniques to survey, identify, and locate radio frequency energy signatures within a given geographic area such as Kennedy Space Center's launch area. The survey mission will use radio interferometry techniques to create radio frequency "images" of the surveyed area. These images will show the locations of all radio frequency activity within an area. The intent is to capture and average a set of images to establish the nominal radio frequency baseline for the area.

Once a baseline is established, real-time radio frequency surveys will be instantly compared to the nominal baseline to detect the existence of radio frequency spectral anomalies. In addition to identifying these anomalies, the time difference of arrival and radio interferometry techniques provide the capability to determine precise locations of radio frequency activities. Therefore, Range Safety can quickly and cost effectively locate the spectral anomaly source and initiate steps to mitigate the source without delay.

Phase I Efforts

During the Phase I efforts of the contract, the contractor's system, which is permanently located in the Melbourne area and covers 15 square miles, was able to locate the radio frequency activity to within less than 100 meters. The figure shows a typical network of seven remote sensors yielding optimum range coverage with economy of hardware. A standard Ethernet link allows the base station used for monitoring the sensor system to be remotely located.

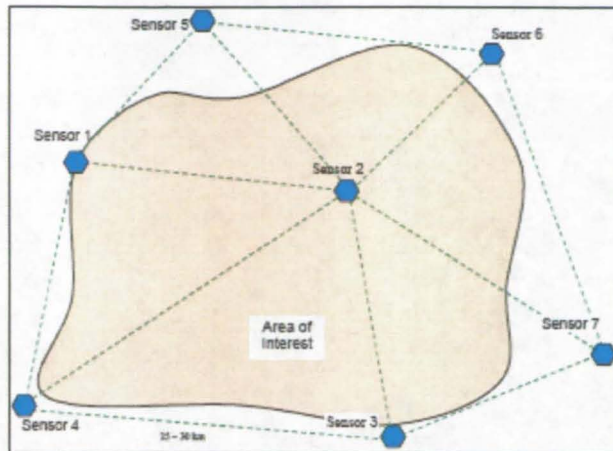


Figure 2.1 - Network of Remote Sensors

Capabilities of the System

The capabilities that the automated range surveillance using radio interferometry and time difference of arrival location techniques provide are listed below:

- Facilitate the expedient clearing of ranges by identifying and pinpointing sources of suspicious radio frequency energy emissions
- Increase Range Safety's ability to preemptively identify and locate potential range intrusions
- Reduce the vulnerability of operations to emission interference whether due to inadvertent or hostile acts, by identifying and locating sources of potential threats
- Allow an area to be remotely monitored in real-time from thousands of miles away
- Lower costs in the overall process of insuring clear and safe range and other restricted area operations

Currently, no commercial systems that offer all of the capabilities described above are available. This system will dramatically decrease the time and expense associated with clearing the range while simultaneously increasing safety by identifying and locating threats from interference, whether unintentional or hostile in nature.

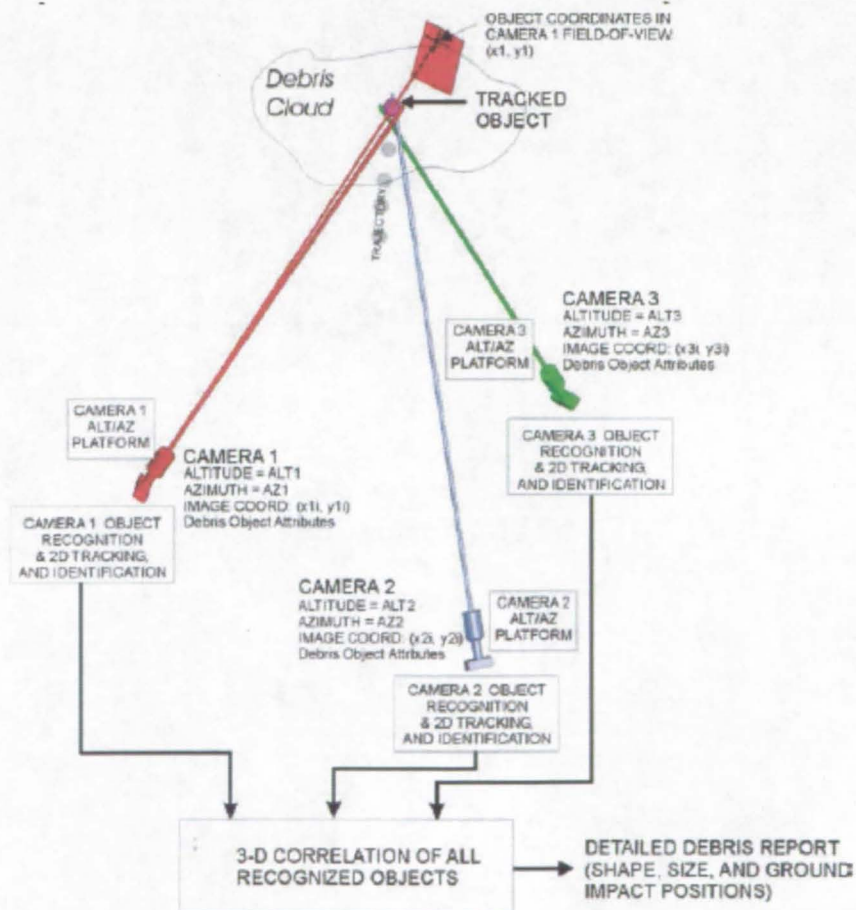
Soneticom successfully met all the objectives for its 2005 Small Business Innovation Research Phase I contract. The Phase I efforts proved that radio interferometry, normally used for high-resolution imaging of celestial sources, could be used for terrestrial applications. With the success of Phase I, Soneticom submitted a Phase II proposal that would enhance the system's accuracy and decrease the data processing time so a viable system could be built for the commercial industry. Soneticom's Phase II proposal was selected with the contract currently being negotiated and contract award expected in December 2006.

Automated Optical Tracking and Three-Dimensional Object Recognition

Most launch accidents happen shortly after lift-off when the vehicle is still within a few tens of kilometers from the launch pad. In this region, an optical system for tracking and identifying debris may be more versatile and less costly than conventional radars. A Phase II Small Business Innovation Research contract has been awarded to OPTRA, Inc. to develop techniques to track and construct three-dimensional views of tumbling objects in the atmosphere or space using digital optical tracking images for a variety of missions. These views will be used to determine the approximate geometric sizes and shapes of the objects.

Potential Application

The potential application is to help track and identify debris quickly after an accident or flight anomaly as shown in the diagram below. The data will be provided by sequential digital images from one or more tracking cameras, ideally operating autonomously. The goal is to track and identify between 50 to 100 objects with typical cross-sections varying from tens of square meters down to one square meter or less within several minutes after an accident.



Phase I Investigation

During the initial Phase I investigation that ended in 2006, OPTRA developed object detection, tracking, and identification algorithms and successfully tested these algorithms on computer-generated objects of various shapes and sizes and on sample real-world image sequences of a Delta II booster separation. OPTRA also determined the minimum size that can be imaged using current technology, the probability of correctly estimating an object's size and shape using identifier qualifiers for each shape class, the resolution capability for accurate identification, and quantified the processing speed and the means for transmitting analyzed data to the command center.

Phase II Goals

The goals of the Phase II effort include the following:

- Refining the detection, tracking, and identification algorithms
- Developing a robust optical system using commercial off-the-shelf equipment
- Investigating the affects of noise, obscurations, viewing angle, tracking errors on the identification probabilities
- Field testing of the system and algorithms by tracking and identifying recreational parachutists

Processor for Real-Time Atmospheric Compensation in Long-Range Imaging

Range surveillance and launch tracking are critical components of space exploration because of their impact on safety, cost, and the overall mission timeline. Because of the difficulty of verifying a cleared range, launch delays are common and will increase as spaceports are developed in new areas. To expedite range clearance and enhance vehicle tracking, it is vital to see accurately and clearly through the atmosphere. However, the quality of images taken with long-range optical systems is severely degraded by atmospheric movements in the path between the region under observation and the imaging system. In fact, as distances increase, atmospheric turbulence is often the dominating source of noise in infrared and visible imaging applications.

Fortunately, image processing algorithms, such as the bi-spectrum speckle imaging method and control grid interpolation, have been developed to help compensate for these disturbances. Even so, these image processing algorithms by themselves are not enough. Specifically, atmospheric compensation algorithms are computationally intensive, which prevents even top-of-the-line personal computers from evaluating them in real time. The necessary algorithms can easily require several seconds to process a single frame and real-time video requires several dozen frames per second—a two order-of-magnitude difference! In 2005, a Phase I Small Business Innovation Research contract was awarded to EM Photonics, Inc. of Newark, Delaware to develop a processor for real-time atmospheric compensation in long-range imaging.

Phase I Approach

The technology being developed is an accelerated solver for a speckle imaging method developed by Carmen Carrano at Lawrence Livermore National Lab. The method takes several seconds of compute time on a modern personal computer to process one image frame. The Small Business Innovation Research approach is to reformulate the algorithm and implement it in hardware using a field programmable gate array as a reconfigurable computing device.

Field programmable gate arrays on the market today contain millions of logic blocks. Algorithms implemented in software languages such as C can be compiled to a direct implementation in field programmable gate array hardware with orders of magnitude performance improvement. The speckle imaging computational problem can be broken up and solved by many parallel hardware blocks in the array and the individual results recombined to produce the resulting image. The overall objective is to be able to process high definition 720p 60 frames per second video in real-time.

Phase I Results

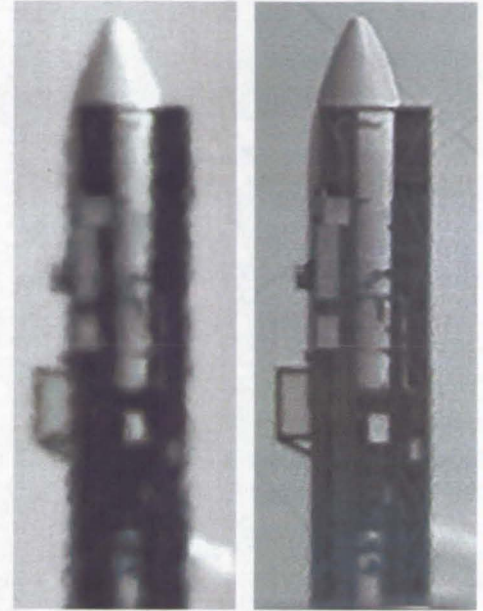
In Phase I of the Small Business Innovation Research contract, EM Photonics was able to verify the approach by reformulating the algorithm and partially implementing it on a field programmable gate array resulting in a 40X speed improvement over the software only version. Only a small piece of the solver was actually implemented on the array. The bulk of the work in Phase I was benchmarking and reconfiguring the code to lend itself to field programmable gate array implementation. EM Photonics successfully met all the objectives for its 2005 Small Business Innovation Research Phase I contract.

At the final demonstration, they were able to process (albeit at 1 frame per second due to the limited implementation) high-definition recorded launch video samples to prove the increase in speed and image enhancement capabilities. An excerpt from one of these samples is shown in the photograph of the Pluto New Horizons spacecraft.

Phase II Goals

With the success of Phase I, EM Photonics submitted a Phase II proposal. The goal for Phase II is to complete the implementation of the entire algorithm in the field programmable gate array and achieve the real-time objective. The company is proposing to deliver a desktop workstation (personal computer) solution using a co-processing board developed for another product. The workstation could process video from a central control room type location either during or post launch working on recorded video. The company is also proposing to provide an integrated embedded solution suitable for attaching directly to an imaging system in the field. EM Photonics Phase II was selected for award with a contract expected in December 2006.

Currently there are no commercial systems available that provide this type of image enhancement and compensation for atmospheric disturbance. EM Photonics has other field programmable gate array based hardware accelerated solver commercial products on the market and, if successful with Phase II, has several potential customers for this product.



Pluto New Horizons Imagery

Speckle enhancement of the launch of the Pluto New Horizons spacecraft. This imagery was processed with the prototype solver developed in Phase I.

GPS Metric Tracking For the ARES Launch Vehicles

On December 21, 2004, the President of the United States authorized a new national policy that established guidelines and implementation actions for United States space transportation programs and activities to ensure the nation's ability to maintain access to and use space for U.S. national and homeland security and for civil, scientific, and commercial purposes. That policy states:

The Federal space launch bases and ranges are vital components of the U.S. space transportation infrastructure and are national assets upon which access to space depends for national security, civil, and commercial purposes. The Secretary of Defense and the Administrator of the National Aeronautics and Space Administration shall operate the Federal launch bases and ranges in a manner so as to accommodate users from all sectors and shall transfer these capabilities to a predominantly space-based range architecture to accommodate, among others, operationally responsive space launch systems and new users.

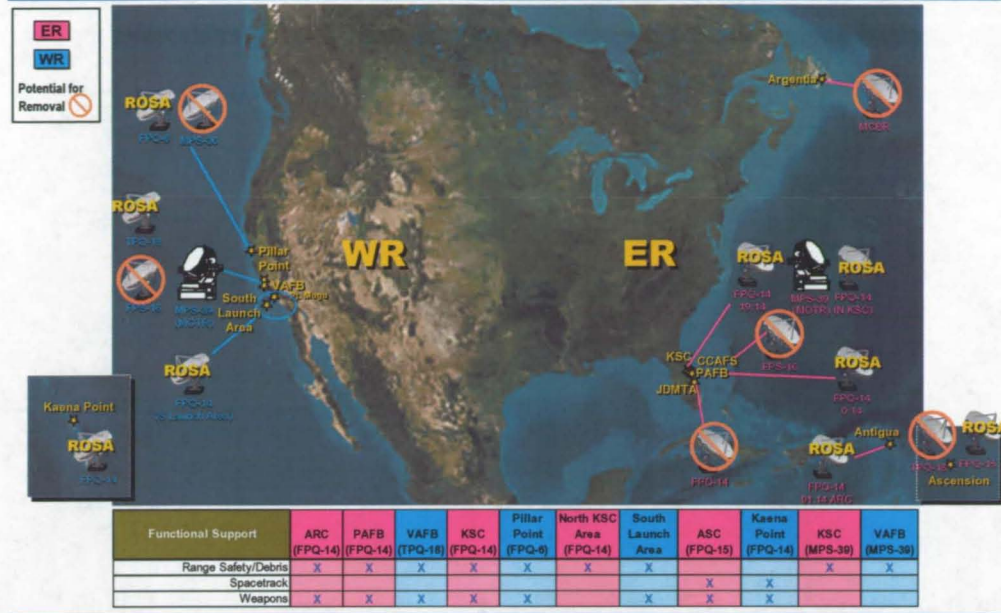
As a logical first step toward a space-based range architecture, the United States Air Force Space Command will require the use of GPS metric tracking for all vehicles launched at the Eastern and Western ranges by January 1, 2011. This new requirement has been planned and discussed by the Air Force Space Command since December of 1997 and was communicated to NASA again during the May 2006 meeting of the Department of Defense/NASA Space Partnership Council.

The key driver for the change is to reduce life cycle costs associated with the launch ranges while enhancing range capabilities to support operationally responsive space missions by transitioning to a space-based approach. As can be seen in the slide presented during the Partnership Council meeting, one way of achieving the needed cost savings is to reduce the number of operational radars by relying on GPS metric tracking data from the launch vehicles to provide one source of the required surveillance information.



U.S. AIR FORCE

Notional "To Be" Radar Architecture



The GPS metric tracking requirement was formally communicated to NASA via a policy memorandum from Dr. Ronald M. Sega, Under Secretary of the Air Force. The memo states: "In order to comply with national space transportation policy on space-based launch ranges, AFSPC will require the use of GPS metric tracking for all vehicles launched at the Eastern and Western ranges by January 1, 2011."

The GPS metric tracking requirement was accepted on behalf of the Agency by Michael F. O'Brien, Assistant Administrator for External Relations, in a September 8, 2006 memorandum to Dr. Sega. The memo states:

"As the Administrator mentioned at the May 25, 2006, Partnership Council, NASA believes that your approach takes us in the right direction. As we define the implementation approach for GPS metric tracking, NASA plans to include GPS metric tracking capability as a part of the launch vehicle acquisition process for vehicles that will launch after 2010, with the understanding that the Air Force will make GPS metric tracking a standard part of the range infrastructure with which those NASA vehicles will interface."

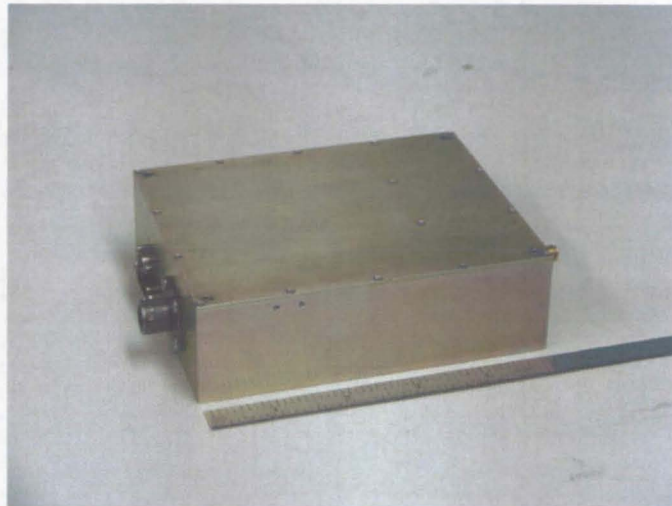
Therefore, the Constellation Program's **ARES** launch vehicles will use GPS metric tracking for ascent flight operations.

Low Cost TDRSS Transceiver

The Low Cost Tracking and Data Relay Satellite System (TDRSS) Transceiver (LCT2) project is developing a cost-effective flight transceiver geared toward suborbital and launch vehicle applications. The [Suborbital and Special Orbital Projects](#) at Goddard Space Flight Center's Wallops Flight Facility initiated the effort. The reason for the development arose from a need for affordable flight hardware for smaller, lower cost missions that could realize operational savings by using the NASA Space Network to supplement or replace ground-based assets. Cost savings have been achieved by integrating the digital and analog circuits, implementing the modulator and demodulator digitally, and not requiring the level of parts selection and radiation tolerance needed for on orbit spacecraft.

Initial Development Phase

The transceiver development has been broken into several design phases. The initial phase covered development of a unit with S-Band transmit capability only, with 10 to 20 watts of radio frequency output power in the 2200 to 2300 megahertz band. The objectives of this first phase were to validate that the overall transceiver enclosure configuration, power distribution, printed circuit board mounting, and signal isolation met flight level environmental constraints. This phase was completed in April 2006.



The phase one transmitter design incorporates a Xilinx Virtex-II field programmable gate array for digital intermediate frequency signal synthesis and baseband data filtering for an optional direct radio frequency quadrature modulator integrated circuit. The unit has demonstrated radio frequency compatibility with the Space Network in both spread and non-spread modes. One unit has flown on an Air Force expendable launch vehicle to support an over-the-horizon telemetry link. Two additional units have been integrated into payloads (not yet launched) for launch and early orbit telemetry support through the Space Network.

Second Development Phase

The second development phase, which is in progress, covers development of the receiver module for processing the TDRSS forward link at 2106.4 megahertz. A radio frequency front end and intermediate frequency gain stage are being incorporated into the present enclosure configuration. The intermediate frequency will be digitized and the correlator and modulator will be implemented digitally in a Virtex-4 field programmable gate array.

A prototype is planned to be available for testing in the summer of 2007. The new transceiver board that includes the receiver functionality will also contain the hooks to interface to a [command and telemetry processor](#)—being developed by Kennedy Space Center—all packaged in a single unit. Once the fully functional transceiver has been tested and performance verified, flights of opportunity will be identified for in-flight evaluation.

Other Related Efforts

Two other LCT2 related efforts are also planned for 2007. First, the high power S-band amplifier will be redesigned with a Gallium Nitride transistor amplifier, that will be nearly twice as efficient as the present design. Second, work is beginning on design of a Ku upconverter module that will drop into the present amplifier well. The result will be a low radio frequency power (< 20 dBm) Ku modulator that can drive a higher power external solid state amplifier or traveling wave tube. Quadrature phase shift keying data rates greater than 150 megabits per second will be achievable using the direct radio frequency quadrature modulator that is in use on the present design.

The LCT2 development team has been managed by NASA and consists of both civil servant and contractor members. The primary engineering contract support has been provided by LJT & Associates from Columbia, Maryland. Initial mechanical and thermal analysis was supported by the Instrumentation Development Group at Johns Hopkins University. Presently, the Mid-Atlantic Institute for Space Technology—a consortium made up of area government, industry, and academic entities—is providing engineering and program support.

Space-Based Range Command and Telemetry Processor

Kennedy Space Center has developed a partnership with Wallops Flight Facility and is working closely with Wallops on a current project to develop a light weight, low power range safety unit for use in space-based applications. The range safety unit will show that with today's technologies, it is possible to meet both the range safety requirements and the space application requirements of size, weight, and power. The range safety unit will have the following capabilities:

- Receive and process forward link commands
- Receive and process GPS data
- Send return link data via a satellite relay that meets the required link margin for range safety

It is anticipated that the first test flight of the range safety unit will be on a sounding rocket.

The range safety unit is based on an integrated architecture and consists of four circuit boards using the latest technologies. The first board is the modulator board being developed by Wallops Flight Facility. This board provides the radio front-end functions. The second board is the command and telemetry processor being developed by Kennedy Space Center's [Advanced Development System Division](#). This board provides the processing functions.

The commercially available GPS receiver is the third board and the fourth board is the power management board also being developed by Wallops Flight Facility. The power management board converts the standard 28 voltage input to the appropriate voltages. The boards are contained in an enclosure that is less than 125 cubic inches and weighs less than six pounds.

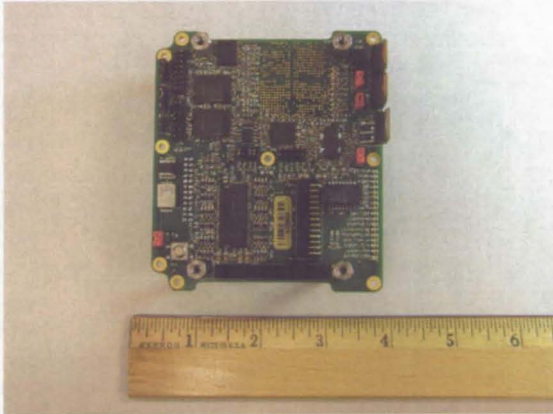
Command and Telemetry Processor Design

The command and telemetry processor design is based on a field programmable gate array with an embedded processor core. The field programmable gate array provides the flexibility that allows the command and telemetry processor to be programmed for different functions and the processor is used to execute code. The command and telemetry processor receives forward link commands via the modulator board interface and processes the commands in the field programmable gate array. Similarly, the command and telemetry processor receives GPS data via the GPS board interface and processes the data in the field programmable gate array.

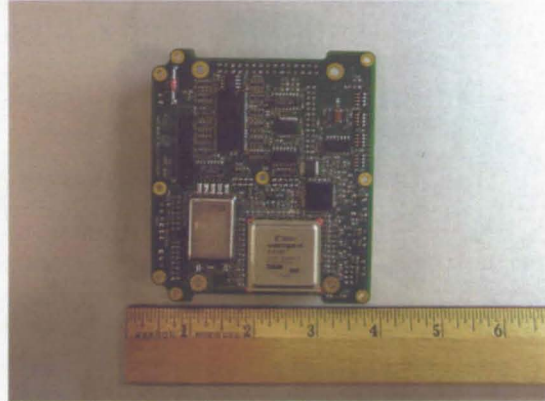
For the return link, the command and telemetry processor formats and sends return link data to the modulator board that includes range safety unit status data, command status data, and GPS data. One Ethernet and several serial interfaces are available on the command and telemetry processor for control and data exchange. The field programmable gate array is programmed through a standard Joint Test Action Group (JTAG) interface available on the command and telemetry processor.

Command and Telemetry Processor Development

The command and telemetry processor is currently in the development phase where the design and implementation of the circuit board has been completed as shown below. The design and programming of the field programmable gate array is partially complete where the serial interface, Ethernet interface, GPS interface, configuration EPROM functions and boot flash functions have been implemented. Once the command and telemetry processor and GPS boards have been tested together, the rest of the boards will be integrated and a functional test will be performed on the range safety unit.



Top Side of Board



Bottom Side of Board

Special Interest Items

Distant Focusing Overpressure

Distant focusing is defined as *an atmospheric phenomenon that can produce greatly enhanced overpressure due to sonic velocity gradients with respect to altitude*. These enhanced overpressures can break windows in distant communities, which may result in personal injury. Distant focusing overpressure, sometimes referred to as *far field blast overpressure*, is of concern in the event of a large explosion on or around the launch pad and occurs only under certain meteorological conditions.

A variety of launch accident scenarios may lead to an on- or near-pad explosion. Examples include an intact vehicle impact with the ground or tower, a partial vehicle break-up that produces ground impacts of liquid propellant tanks or solid rocket motor segments, or vehicle tip-over at the pad due to one or more of the solid rocket motors not firing properly. Mitigation from these near field overpressure hazards includes establishing a quantity-distance criteria or evacuating personnel from areas of high risk. Data from near field overpressure plus atmospheric data is used to determine distant focusing overpressure.

Near field overpressure waves travel supersonically through the atmosphere and are not significantly affected by differing meteorological conditions as they expand radially from the explosion's source (picture at right). As the wave energy dissipates to levels less than a few pounds per square inch, the wave's propagation pattern changes to more closely resemble a standard acoustic wave. Therefore, the prediction of blast wave effects at intermediate to long distances can be based on the same basic principles that describe the propagation of acoustic waves, namely Snell's law.



Determining the Potential for Focusing

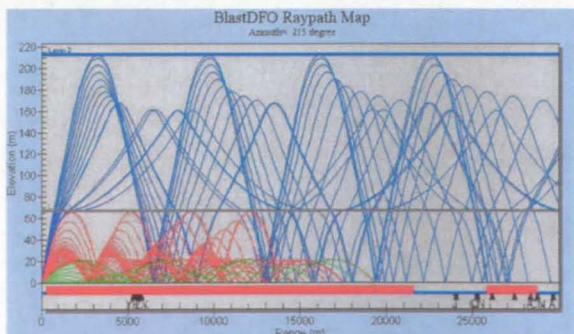
To determine the potential for focusing, atmospheric conditions must be monitored and evaluated. Two atmospheric parameters are paramount in determining acoustic wave propagation: wind speed gradients and temperature gradients. Relative humidity and pressure are also involved to a lesser extent. From these parameters, a sonic velocity profile (with altitude) is determined for each azimuth around the launch pad to determine if conditions are favorable for overpressure focusing. Sonic velocity is *the calculated speed of sound plus a directional wind speed component*. In basic terms, as the sonic velocity decreases with altitude, wave fronts are refracted upward or away from the ground. As the sonic velocity increases with altitude, wave fronts are refracted downward or toward the ground.

Understanding the attenuation conditions and their effect on overpressure strengths at population receptors, the risk of breaking windows and causing serious injuries can be calculated. Because distant focusing overpressure is not a hazard that can normally be contained within the base boundaries, a risk-based approach for evaluation has been accepted by the range community. Flight safety analysis is used to establish launch commit criteria, usually expressed in terms of casualty expectation (E_c), that protect people from any hazard associated with far field blast window breakage effects due to potential explosions during launch vehicle flight.

BLASTDFO Computer Model

A physics-based computer model, commonly referred to as *BLASTDFO*, is used to assess the risk associated with far field blast overpressure. The model was developed by ACTA Inc. and includes modules and databases to calculate and assess potential explosive yields, acoustic ray traces, receptor overpressures, glass breakage, base and community population and window information, human vulnerability, and individual and collective casualty expectation.

Just before launch, the distant focus overpressure flight analyst evaluates current weather conditions and identifies any areas that may be subject to enhanced or focused overpressure.

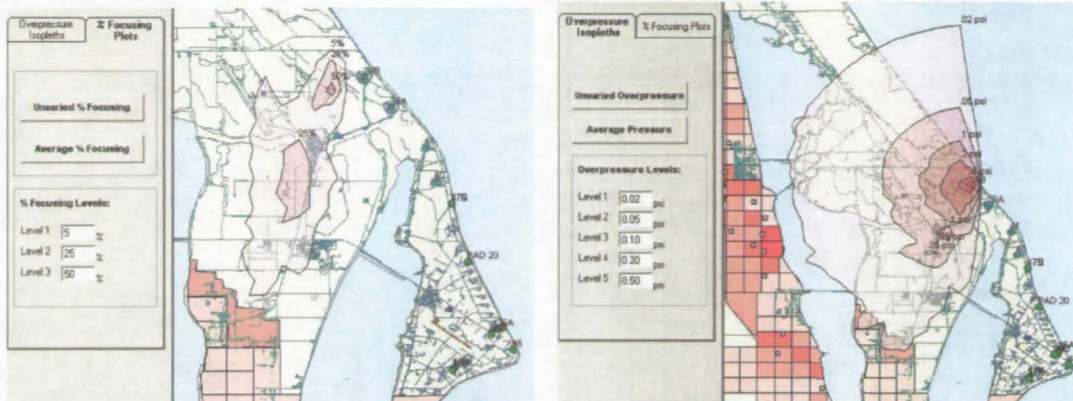


Ray tracing plots, like the one shown to the left, are analyzed to determine if enhanced or focusing conditions are present. These regions represent the areas where glass breakage is most likely to occur. Average overpressures, window breakage, and casualty expectations are then calculated. If either the individual or collective casualty risk exceeds launch commit criteria and cannot be mitigated to

acceptable levels, the analyst will recommend a launch hold.

Two products of BLASTDFO are shown below. On the left is an example of isopleths of probability of focus. On the right is an example of peak overpressure. Distant focus overpressure hazards occur almost instantaneously with the anomaly, so these

products are forwarded to emergency planning managers to aid in any required emergency response preparation.



Fortunately, on-base distant focus overpressure risk is fairly easy to mitigate. When facilities at higher risk are identified, personnel are requested to move away from windows or simply go outside (away from windows) to watch the launch. Not a bad compromise!

Space Florida

The nation is seeing the birth and early growth of a new space tourism industry and NASA's Vision for Space Exploration has initiated the Constellation and Commercial Orbital Transportation Services programs. These events bring new opportunities and challenges to Florida's space community.

To address these opportunities, a commission was formed to study and make recommendations concerning Florida's role in the future of commercial launches. The *Governor's Commission on the Future of Space and Aeronautics in Florida* final report highlighted two customer service areas that are critical to helping make the Eastern Range more "user friendly." The areas are:

- Customer Service Process, including the Universal Documentation process
- Flight Safety Approval Process

Another result of the Commission's report was a restructuring of Florida's space-related organizations into one organization called Space Florida (<http://www.spaceflorida.gov>).



To correct the customer service concerns cited above, a contract was signed in August 2006 between Florida Space Authority (now Space Florida) and a contractor team to provide consulting services and flight safety approval assistance to new commercial launch customers. One of the program elements is to establish a training program to help new customers understand the Eastern Range flight safety approval process, the Universal Documentation System, and range requirements.

Training Program

NASA's Kennedy Space Center, the 45th Space Wing Range Safety Office, and the Federal Administration Association, Office of the Associate Administrator for Space Transportation are developing training programs to increase the effectiveness of their employees and to aid their government customers in navigating through range safety requirements.

In coordination with the Air Force, Kennedy Space Center, and the Federal Aviation Administration, the Space Florida contractors will develop a range safety training program tailored specifically for commercial launch customers. Design documents are already complete and new courses should be available in early 2007.

The contractors are currently providing valuable consulting services to new and potential Space Florida customers, including the Commercial Orbital Transportation Services contractors whose logos are shown to the right.

Flight Safety System

Another exciting element of the Space Florida program is the development of alternate, or pre-approved, flight safety systems. The contractor will identify available flight safety system components and investigate future flight safety system options and concepts for government furnished or government approved flight safety systems.

The contractor will develop several alternative

concepts for a feasible system, dubbed *universal flight safety system*, along with minimum performance requirements. Options will include such concepts as government furnished, government approved, one size fits all, launch vehicle class unique systems, and entire integrated systems versus subsystem/component concepts. The contractor will coordinate preliminary concepts with Space Florida, the 45th Space Wing Range Safety Office, and NASA and, as a team, select final concepts to pursue.



NASA Expendable Launch Vehicle Payload Safety Program

NASA Headquarters Office of Safety and Mission Assurance established a NASA team to update the expendable launch vehicle payload safety review process and replace the current NASA-STD-8719.8, *Expendable Launch Vehicle Payload Safety Review Process Standard*, with a NASA procedural requirements document. The team's goal is to develop a program with improved structure and processes for ensuring NASA expendable launch vehicle payloads are consistently designed, transported, processed, tested, integrated with the launch vehicle, and launched safely. The new process will be coordinated and implemented jointly with the Air Force approval process (for launches from Air Force ranges) and will retain the Payload Safety Working Group and a phased safety review approach.

Chapters One and Two of the new *Expendable Launch Vehicle Payload Safety Program* NPR, are complete and in the review cycle. Chapter One documents the agency policy for Expendable Launch Vehicle Payload Safety and Chapter Two describes the Safety Review and Approval Process. Technical design and operational requirements for the payload and ground support equipment are presently being developed combining NASA and Air Force requirements (AFSPCMAN 91-710, *Range Safety User Requirements Manual*).

An Expendable Launch Vehicle Payload Safety and Mission Success Conference was held February 6 - 8, 2007. For more information, you can access information about the conference website at [insert link to website for conference](#)

Before the conference began, an informational exchange session was held on February 5 to address Expendable Launch Vehicle Payload Safety Program development, requirements, and implementation. An overview of the Program's policies, processes, and requirements will be presented and discussed. In addition, training courses are being developed for working group members and engineers as well as program managers.

[\[Insert photo of Calypso payload here.\]](#)

Subminiature Flight Safety System

A new technology currently under development is the subminiature flight safety system shown in the picture below. Concept development for this system began in May 2004 and was completed in September 2005. During this stage, requirements were developed, technology capabilities were derived, and approximate developmental costs were researched. A systems engineering analysis was also performed on the subminiature flight safety system during this time to improve and solidify feasible options and capabilities of the system.



Representative Discrete Components
6 lbs - 102 in³



SFSS
1.25 lbs - 10 in³

System Status

Phase I began in September 2005 after concept development was complete. This phase focused on developing and submitting Central Test and Evaluation Investment Program documentation to Tri-Service Representatives. All documentation and reports have been submitted for Phase I and, as of this publication, the subminiature flight safety system program is awaiting approval from Central Test and Evaluation for Phase II funding.

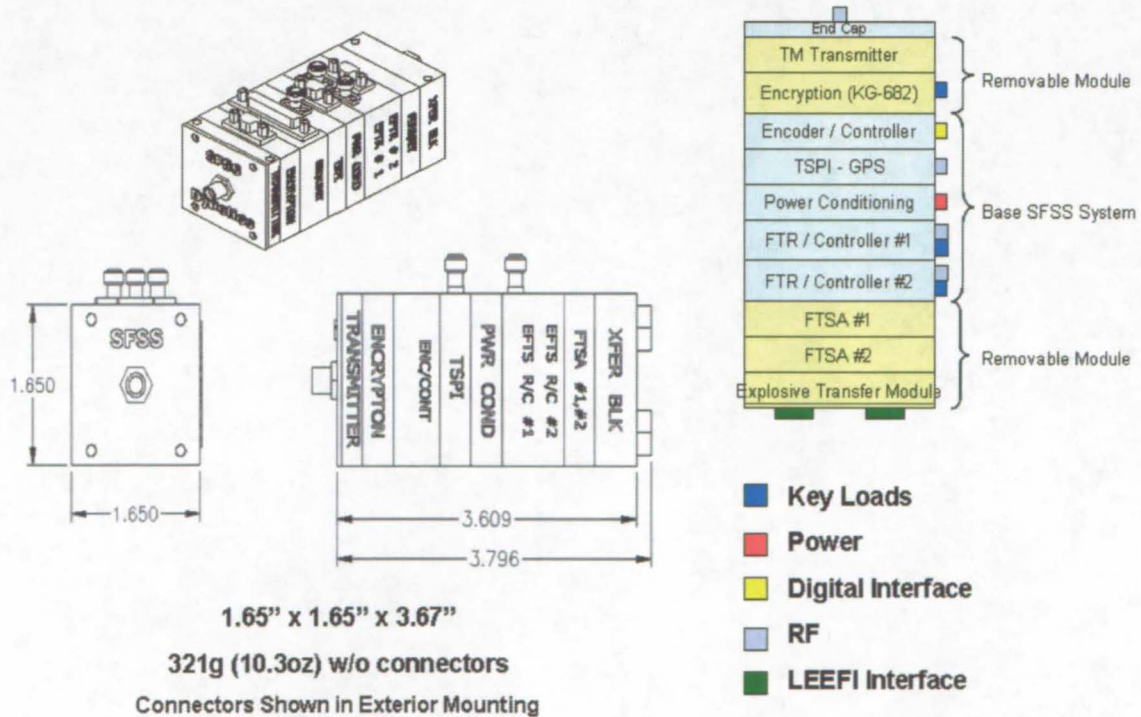
Phase II will include development of the system specifications and then a contract awarding process to build, test, and implement the subminiature flight safety system. This phase will also include qualification testing for components and eventual flight tests and demonstrations and most likely will reach completion in late 2009 or early 2010.

Subminiature Flight Termination System Features

Some of the features and possible capabilities of the subminiature flight safety system are listed below and shown in the following diagram:

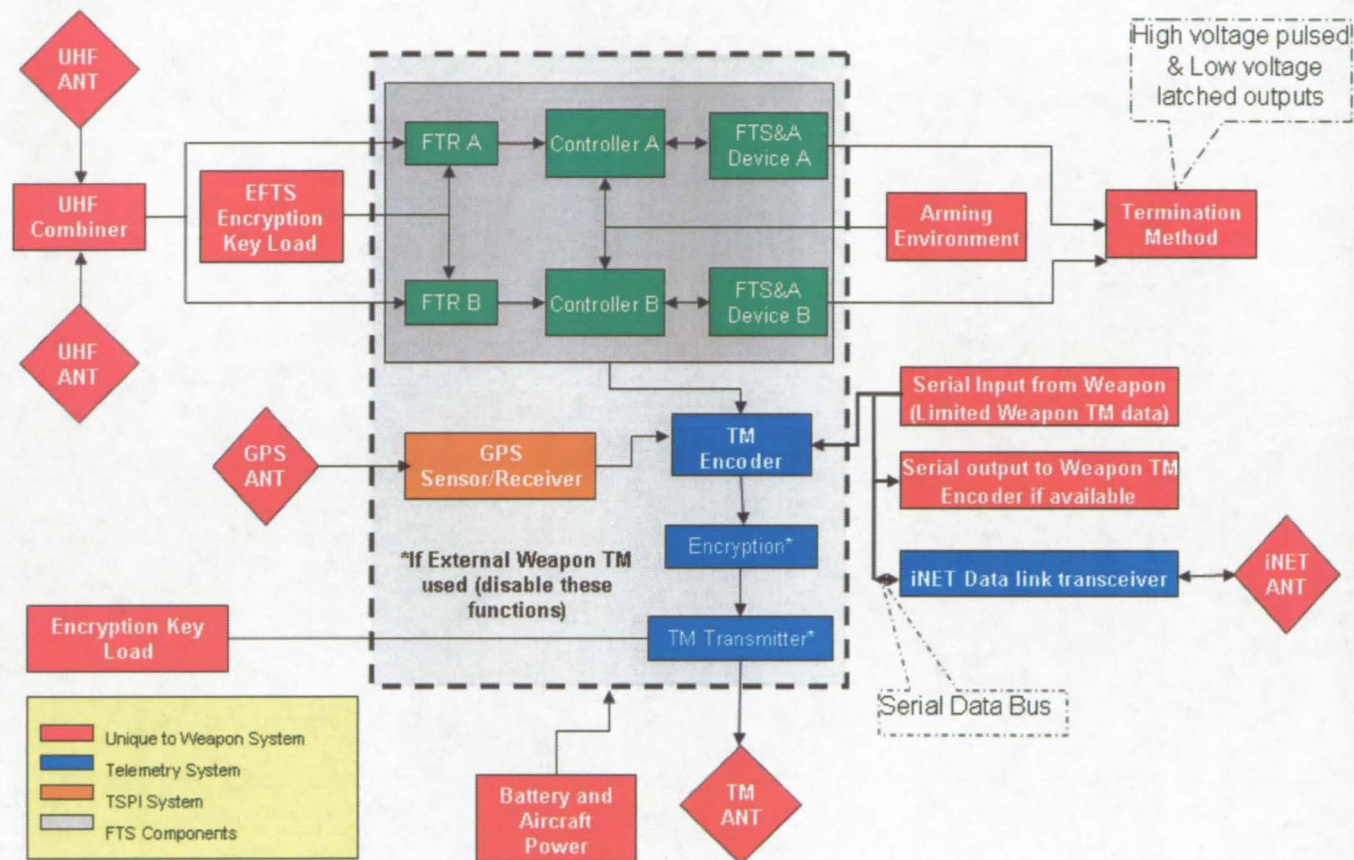
- Flexible, wide-range missile capabilities, such as air-to-air, surface-to-air, surface-to-surface, and air-to-ground
- Ability to operate without radar tracking infrastructure
- Low cost, less than \$35,000
- Telemetry capability for system health status (encrypted)
- Time and space information to provide accurate weapon system position (encrypted)
- Dual, redundant flight termination receivers/controllers
- Approximately 10 to 14 in³ in size
- Encoder and encryption capability
- Dual safe and arm controllers/inhibitors

The system also meets all [RCC 319, Flight Termination Systems Commonality Standard](#) requirements



Subminiature Flight Termination System Architecture

The subminiature flight termination system is being designed in a modular format to make several different options available. This format will make the unit more flexible to the needs of the user or program. For example, if the program does not wish to encode the telemetry downlink, then that module can be eliminated from the system without causing any disturbance with other systems or modules. System architecture for the subminiature flight termination system includes a variety of components and modules shown in the graphic below.



The enhanced flight termination system could be used in conjunction with the subminiature flight termination system. The enhanced flight termination system ground equipment (encoders, monitors, triple data encryption units) encrypts messages and sends them to the command transmitter system, consisting of Legacy modulators, exciters, and high power amplifiers. The command transmitter system relays the enhanced flight termination system messages to the vehicle via the command transmitter. Ultra high frequency antennas pick up the transmitted enhanced flight termination system signals and send them to the flight termination receiver.

From there, the commands are processed and sent to the flight termination controllers for action. The controller then sends a signal to the flight termination system safe and arm devices to initiate destruct if termination is necessary. The unit also contains a GPS sensor/receiver that will provide accurate GPS tracking for range ground stations. The telemetry being retrieved from the vehicle will be encrypted within the subminiature flight termination system unit for transmission to range ground stations.

Even though this system is not yet complete, the technology involved and the determination exhibited in making this program succeed are remarkable. Range Safety will continue to work with the subminiature flight safety system program to ensure that the newest, groundbreaking methods and technologies are available for all ranges and users as desired. Range Safety will also continue working with the program to ensure that public safety is a top priority in designing this system.

Status Reports

Kennedy Space Center Range Safety Representative

The Kennedy Space Center Range Safety Representative is tasked with implementing NASA policy and keeping the Agency Range Safety Manager informed of all activities related to range safety. Over the course of the past year, the Range Safety Representative supported a myriad of range safety activities, ranging from pre-launch policy interpretation and guidance to providing on-console support during launch campaigns.

Constellation Program

For the [Constellation](#) Program, the Kennedy Space Center Range Safety Representative was involved in providing a top-level tailored version of [NPR 8715.5](#) for use in driving architectural as well as system level requirements. In addition, a number of Constellation documents such as those listed below were reviewed:

- Constellation Architecture Requirements Document
- System Requirements Document
- Safety, Reliability, and Quality Assurance Plan

The resulting support will capture applicable Range Safety requirements for the program to implement.

The Range Safety Representative represented the Agency on the Crew Exploration Vehicle Smart Buyer team. This effort involved providing the Constellation Program with an in-house design using subject matter experts across the Agency to assist the program in the conduct of proposal evaluations. The Range Safety Representative also provided continued support to the [Launch Constellation Range Safety Panel](#).

Space Shuttle Program

For the Space Shuttle program, the Range Safety Representative was involved in the development and publication of a Kennedy Space Center Launch and Landing Range Safety Risk Management Plan as well as a Landing Implementation Plan. These plans detail how Kennedy Space Center and the Space Shuttle program intend to meet the individual and collective risk criteria found in NPR 8715.5. Launch and entry risks estimates were evaluated for STS-121 and STS-115 and both sets of results were well within NPR criteria.

The Range Safety Representative also provided continued support to the Shuttle Range Safety Panel and supported STS-115, STS-121 and STS-116 launches on console in the Range Operations Control Center.

Launch Services Program

For the launch services program, the Range Safety Representative supported a number of NASA expendable launch vehicle campaigns, including [Calypso](#) [CloudSat](#) and [Pluto New Horizons](#). This effort involved attending all the NASA and Air Force Safety

readiness reviews and ensuring NPR requirements were being met during the respective launch countdowns.

Agency Activities

For Agency activities, the Range Safety Representative served as NASA point of contact to the Range Safety Group and supported several committees charged with developing or rewriting nationwide standards on a number of important range safety issues. These topics included developing reusable launch vehicle and uninhabited aerial vehicle requirements and a rewrite of RCC 321, *Common Risk Criteria for National Test Ranges* for risk evaluation and approval.

The Range Safety Representative also led an Agency-wide team through initial planning of a NASA common flight analysis tool development activity. This activity takes a strategic approach by leveraging the talents of individuals and tools within and outside the Agency. It is expected that this effort will result in the ability to share resources in a way that creates greater technical in-house capability across the Agency.

Other Range Safety Activities

Other Range Safety activities that the Range Safety Officer was involved in included the following:

- Documenting approval of range safety non-conformances/variances for all applicable NASA launches
- Publishing Range Safety Variance and Spaceflight Risk Assessment Board processes for Kennedy Space Center, processes describing the steps taken should risk estimates be higher than acceptable per NPR criteria
- Supporting discussions regarding flight termination system frequency migration plans and how they affect future NASA missions
- Supporting discussions relative to meeting secure systems requirements found in NPR 2810, *Security of Information Technology*
- Assisting the Agency Range Safety Manager in developing a Range Safety Operations course for NASA, the last in a series of NASA Safety Training Center taught courses
- Tracking and coordinating audit responses and corrective actions generated from the Wallops Flight Facility and Dryden Flight Research Center Range Safety Assessments conducted in 2005
- Providing Toxic and Distant Focus Overpressure risk analysis support to Wallops Flight Facility for the TAC SAT-2 Minotaur launch

The past year was a challenge in supporting a number of launch and entry campaigns, providing critical early support to the Constellation Program, and continuing to ensure Kennedy Space Center safely implements NASA Range Safety requirements. The coming year promises to be at least as busy and the Kennedy Space Center Range Safety Representative will continue to provide critical support whenever called upon by NASA programs or to address issues that may arise.

Wallops Flight Facility

Wallops Flight Facility has had yet another successful year. The Sounding Rockets Program supported 20 missions including the first flight test of the autonomous flight safety system. The Balloon Program Office supported 13 successful missions while uninhabited aerial vehicle operations grew significantly. The TacSat missions demonstrated the Facility's ability to provide responsive range services. New range technologies continue to be developed and the Wallops Mission Planning Laboratory was brought on line this year.

Sounding Rockets Program

The Sounding Rockets Program had a successful year, supporting 20 missions from Wallops, White Sands Missile Range, and Hawaii. These missions supported NASA Space Science, technology development, and educational outreach experiments, and a variety of Department of Defense projects. The Program experienced a 100 percent mission success rate for the period. The Wallops Safety Office provided operational support and analysis for all these missions.

Autonomous Flight Safety System. Wallops conducted the first flight test of the autonomous flight safety system this year on a sounding rocket mission from White Sands Missile Range. The autonomous flight safety system is an on-board sensor and computer suite designed to assess a launch vehicle's performance against pre-programmed range safety mission rules. When rules are violated, the system sends commands to the vehicle's flight safety system to terminate flight. The White Sands Missile Range flight successfully demonstrated the autonomous flight safety system's ability to correctly determine appropriate on-board decision making. The autonomous flight safety system and Low-Cost TDRSS Transceiver have been packaged and are scheduled to fly as experiments in an upcoming SpaceX Falcon 1 flight from Kwajalein Atoll.

Other New Technologies. Additionally, the Sounding Rocket Program has been demonstrating other new technologies, including a computer-guided hazard avoidance landing system for use on planetary missions, a new fine pointing celestial attitude control system, and a new velocity vector tracking attitude control system for use on suborbital sciences missions. Many of these efforts are collaborative with partners at the Jet Propulsion Laboratory, Langley Research Center, and Kennedy Space Center. The Wallops Safety Office has played a key role in ensuring successful implementation of these missions.

Balloon Program Office

The Balloon Program Office at Wallops Flight Facility conducted 13 missions during 2006. Flight operations were conducted from Fort Sumner, New Mexico; Palestine, Texas; Kiruna, Sweden, and McMurdo, Antarctica. The Wallops Safety Office supported the 2006 balloon flight program by providing flight safety analysis reports for operational implementation for both continental United States and foreign operations. Flights were conducted in support of Space and Earth science payloads as well as developmental test flights for new balloon design and balloon film qualification. Flight durations ranged

from 6 hours to 28 days with the longest flight occurring over Antarctica. The northern hemisphere flight capability was used from Sweden-to-Canada for the second year, with science payload recovery in northern Canada.

The Balloon Program Office continued the ultra long duration balloon development with the test flight of a 6 million cubic foot test article from Kiruna, Sweden in May 2006. (See the picture at the right.)

While the flight did not result in a satisfactory inflation of the balloon, considerable data were collected for use in engineering models that will be used to develop necessary design changes.

Further flight testing of the ultra long duration balloon is planned for 2007. The ultra long duration balloon is being developed to provide extended duration flight, upwards of 60-100 days, at constant float altitudes.

Uninhabited Aerial Vehicle

Uninhabited aerial vehicle operations grew significantly during 2006. Wallops Flight Facility continued a heavy workload with the AAI Aerosonde in support of NASA science missions, including a deployment to Key West, Florida to collect data on early formation of hurricanes.

Additionally, Langley Research Center began frequent operations on the Wallops Island uninhabited aerial vehicle runway with its Global Transport Model operations.



New Range Technologies

Wallops technologists continued development and testing of numerous new range technologies that promise to improve the responsiveness and cost of launch operations. The Low-Cost TDRSS Transceiver development progressed with a successful operational flight of a 20 watt transmitter-only unit on the Air Force Minotaur I COSMIC mission in January 2006. The Low-Cost TDRSS Transceiver enables the relay of flight data to the ground without requiring line-of-sight, through use of NASA's TDRSS satellites at a small fraction of the cost of existing systems. Progress continues on developing a 40 watt transmitter as well as with the development of the receiver subsystem.

Prototype hardware has also been developed for a new low-cost flight S-Band telemetry phased array antenna and beamformer. Once operational, this system promises significantly increased data rates. Testing of the initial unit is underway, and a flight test is anticipated for mid-2007. Planning is also underway for Ka and Ku-Band systems as well.

TacSat

On 16 December 2006, a Minotaur I rocket carrying the Air Force Research Laboratory's TacSat-2 satellite and NASA's GeneSat-1 microsatellite was successfully launched from Wallops Flight Facility. (See picture at right.) The TacSat-2 mission demonstrated Wallops' ability to provide responsive range service, by providing spacecraft and launch vehicle integration and launch operations within six months of the Air Force's request.

Two Minotaur 1 rockets are scheduled for launch in 2007 from Wallops carrying the near-field infrared experiment satellite in April and the TacSat-3 satellite in October. In anticipation of these missions, range and range safety personnel spent much of 2006 modernizing facilities, performing pre-mission analyses, and testing.



Demonstration Missions

Wallops personnel are also preparing for the demonstration mission of a new commercial high-performance suborbital rocket, ALV-X1 built by Alliant Techsystems. A launch site pathfinder test of the ALV-X1 verified that vehicle processing procedures and equipment were ready for live motors and flight hardware. The demonstration mission, scheduled for mid 2007, will carry two NASA hypersonics experiments sponsored by NASA's Aeronautics Research Mission Directorate. The first, HyBoLT, is a boundary layer transition experiment developed by Langley Research Center. The second, SOAREX, is an aerodynamic re-entry experiment developed by Ames Research Center. The mission has been designated HSA (HyBoLT, SOAREX, ALV-X1).

Wallops Mission Planning Laboratory

The Wallops Mission Planning Laboratory was brought on line this year. The Mission Planning Laboratory serves as a high fidelity range mission simulator that can be used to assess trajectories, instrumentation coverage, hazard areas, and other critical parameters in the preparation of upcoming missions. Ultimately, the Mission Planning Laboratory will work with launch vehicle hardware systems as a test bed for new technologies.

Dryden Flight Research Center

The [Dryden Flight Research Center](#), located at Edwards Air Force Base, California, is NASA's primary installation for flight research. Over the past 60 years, projects at Dryden have led to major advancements in the design and capabilities of many civilian and military aircraft. The Center is involved in the following:

- Support of operations for the Space Shuttle
- Development of future access-to-space vehicles
- Conduct of airborne science missions and flight operations
- Development of piloted and uninhabited aircraft test beds for research and science missions

Range Safety operations at Dryden are managed by the Range Safety Office. Under an alliance agreement with the Air Force Flight Test Center, Edwards Air Force Base, the Dryden Center Director established the Range Safety Office to provide independent review and oversight of range safety issues.

The Range Safety Office also supports the Center by providing trained flight termination system engineers, range safety risk analysts, and range safety officers to provide mission and project support. In addition, the office supports the NASA Range Safety Training Program by providing the uninhabited aerial vehicle perspective in the development of range safety courses.

Dryden continues to support the testing of a wide range of uninhabited aerial vehicles and is involved in various other projects that are described below.

Altair

General Atomics Aeronautical Systems' [Altair](#) uninhabited aerial vehicle successfully completed several 20 plus hour flights with NASA Ames Research Center and National Oceanic and Atmospheric Administration scientific payloads in October. The purpose of the flights was to demonstrate the feasibility of a high altitude, long endurance uninhabited aerial vehicle to provide real-time data for the detection and surveillance of wildfires in the Western United States.

Model-Type Uninhabited Aerial Vehicles

The [Autonomous Soaring Uninhabited Aerial Vehicle Project](#) used RnR Products' [Cloud Swift](#) sailplane to demonstrate that using thermal lift could significantly extend the range and endurance of model uninhabited aerial vehicles without a corresponding increase in fuel requirements.

Blended Wing Body Low Speed Vehicle

The [blended wing body low speed uninhabited aerial vehicle](#) is a dynamically scaled version of the original concept vehicle. The primary goals of this test and research project are as follows:

- Study the flight and handling characteristics of the blended wing body design

- Match the vehicle's performance with engineering predictions based on computer and wind tunnel studies
- Develop and evaluate digital flight control algorithms
- Assess the integration of the propulsion system to the airframe

Industry studies suggest that because of its efficient configuration, the blended wing body would consume 20 percent less fuel than jetliners of today while cruising at high subsonic speeds on flights of up to 7,000 nautical miles.

Ikhana

NASA's [Ikhana](#) uninhabited aerial vehicle is a General Atomics Predator-B modified to support Earth science missions for the Science Mission Directorate. The aircraft is capable of mission durations in excess of 24 hours at altitudes above 40,000 feet. The aircraft is designed to be disassembled and transported in a large shipping container aboard standard military transports. On-board support systems include a NASA developed [airborne research test system](#), a system that can host research flight control algorithms that test autonomous sensor or autonomous aircraft control concepts.

Orion

The [Orion Project](#) is part of the Agency's [Constellation Program](#). The Orion Project consists of the crew module and launch abort system. Dryden is tasked with conducting a series of flight tests to demonstrate proper operations of the launch abort system and the crew module recovery systems in response to abort events initiated on the launch pad and during the initial ascent phase of flight. The abort flight tests will be conducted at the United States Army White Sands Missile Range in New Mexico.

As can be seen in the description of these projects, Dryden Flight Research Center plays a vital role in advancing technology and science through flight. At Dryden, America's leadership in aeronautics and space technology is demonstrated as the Center continues to push the envelope to revolutionize aviation and pioneer aerospace technology.

NASA Headquarters

The Office of Safety and Mission Assurance at NASA Headquarters works to ensure the safety and success of all NASA activities by developing and overseeing the implementation of Agency-level policies and requirements related to safety, reliability, maintainability, and quality assurance. The NASA Range Safety Program functions as an element of the Office of Safety and Mission Assurance. The Office also approves and promulgates Agency-level range safety policies and requirements, designates the NASA Range Safety Manager, and funds and oversees Range Safety Program activities.

The Headquarters Range Safety Representative is part of the Safety and Assurance Requirements Division of the Office of Safety and Mission Assurance.



The Headquarters Range Safety Representative and other members of the Office worked regularly with Agency range safety personnel and participated in a number of range safety related projects and initiatives throughout 2006. Articles addressing a number of the topics discussed below can be found in this *NASA Range Safety Annual Report*.

Expendable Launch Vehicle Payload Safety

The Office of Safety and Mission Assurance has established a team of personnel with expendable launch vehicle payload safety expertise from throughout the Agency in an effort to develop a new [NASA Expendable Launch Vehicle Payload Safety Program](#). A major accomplishment for this team in 2006 was the finalization of new NASA payload safety policy which was published in Chapter 3 of NPR 8715.3, *General Safety Program Requirements*, dated September 2006. This document includes Agency safety policy applicable to all types of payloads. It establishes the NASA Expendable Launch Vehicle Payload Safety Program and it assigns associated roles and responsibilities. The team also made progress in developing a revised safety review and approval process applicable to all NASA expendable launch vehicle payload projects and associated technical requirements.

Range Commanders Council

The Headquarters Range Safety Representative actively participated in semiannual Range Commanders Council Range Safety Group meetings in 2006 and regularly worked as a member of the Range Safety Group Risk Committee to develop new Range Commanders Council [Range Safety Risk Standards](#), scheduled to be published in 2007.

Space Shuttle and Constellation Range Safety Panels

Office of Safety and Mission Assurance representatives participated in the activities of the [Space Shuttle Range Safety Panel](#) and the new [Constellation Range Safety Panel](#).

Training Development

The Headquarters Range Safety Representative worked with Agency range safety personnel in the development of the new NASA [Range Safety Systems Training Course](#), which was completed and first offered in 2006.

Audits and Assessments

The Office of Safety and Mission Assurance conducted a [programmatic audit of NASA's Orbital Sciences Corporation launch services contract](#) for the Pegasus and Taurus launch vehicles. This audit took place over a 4-week period during April and May of 2006 and included site visits to Orbital Sciences facilities in Virginia, Arizona, and California. The audit included an assessment of Orbital Sciences' implementation of range safety requirements and a review of the flow down of NASA safety policies and requirements into the associated contracts and operational documents.

Office of Safety and Mission Assurance representatives participated in a special review of the [Ultra-Long Duration Balloon Project](#), which is run out of the Goddard Space Flight Center – Wallops Flight Facility. The special review included an assessment of the Project's efforts to satisfy NASA range safety policy and requirements for the testing and operation of this new type of high-altitude balloon.

Research and Technology Development

The Office of Safety and Mission Assurance funds and oversees safety related research and technology development projects throughout the Agency. Range safety projects for 2006 included the [Global Positioning System Operational Information Laboratory](#) at Wallops Flight Facility, the [Joint Advanced Range Safety System Project](#) at Dryden Flight Research Center, and the [Autonomous Flight Safety System Project](#) at Kennedy Space Center and Wallops Flight Facility.

Johnson Space Center

Launch Constellation Range Safety Panel



Late in 2005, it became increasingly clear that there were many questions and issues related to range safety that needed to be coordinated across the multiple **Constellation Program** Projects and organizations. It was time to start addressing some of the early design and requirements issues and open a coordinated dialog with the 45th Space Wing on NASA's new vision and objectives.

In February 2006, the Launch Constellation Range Safety Panel was officially chartered by the Constellation Program and jointly signed by the 45th Space Wing Commander and the program manager.

Highlights of the Launch Constellation Range Safety Panel Charter

Highlights of the Launch Constellation Range Safety Panel charter are included below.

I. **PURPOSE**: This directive establishes the manner in which launch range safety matters will be managed for Constellation program vehicles, including specifying key interfaces with the Department of Defense for launch range safety (primarily the Air Force 45th Space Wing responsible for the Eastern Range).

II. **SCOPE**: All Range Safety activities for elements of Constellation launch vehicle flights and pre-operational test flights are within the scope of this directive. The Launch Constellation Range Safety Panel will:

- Serve as the technical forum to facilitate formulation and joint approval of NASA/Air Force Range Safety policy agreements
- Identify Range Safety requirements and propose tailoring, as required
- Support risk model and analysis tool development (formulation, assumptions, and input data)
- Integrate Range Safety related hardware and software changes
- Monitor Range Safety System design, testing, and implementation
- Initiate and integrate operational Range Safety activities such as operational concepts and procedures, analysis of trajectory design variations, mission planning, flight rules and launch commit criteria development

Note: Entry vehicle range safety is addressed in another directive.

V. **ORGANIZATION**: The Launch Constellation Range Safety Panel is comprised of NASA and Air Force representatives and is the forum for range safety coordination and negotiations between the agencies. The Launch Constellation Range Safety Panel is co-chaired by the 45th Space Wing Range Safety Manager and the NASA Constellation Range Safety Manager. In addition to the chairperson, NASA membership on this panel includes representatives from the following:

- Launch Vehicle Project
- Crew Exploration Vehicle Project

- Kennedy Space Center Constellation Ground Operations Project and Range Safety Representative
- Johnson Space Center Flight Design and Dynamics, Flight Director Office, Astronaut Office, Constellation Operations Integration, and Constellation Systems Engineering and Integration
- Headquarters Constellation Integration and Analysis and Safety, Reliability, and Quality Assurance

In addition to the 45th Space Wing Range Safety Manager, Eastern Range membership on this panel includes representatives from the following 45th Space Wing organizations:

- Range Operations Squadron
- Launch Analysis
- Launch Safety and Analysis

The Launch Constellation Range Safety Panel has strong representation from all of the key program elements and has been very active since its inception. By the end of 2006, the panel had met 15 times, plus supported multiple splinter meetings, and one face-to-face in Florida.

Launch Constellation Range Safety Panel Trajectory Working Group

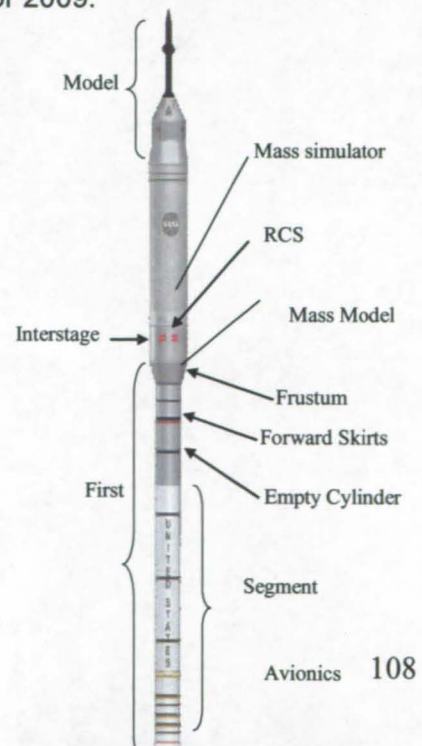
The first sub-group from the Launch Constellation Range Safety Panel was the Trajectory Working Group. This group coordinates the range safety trajectory analysis requirements and manages the distribution of the tasks and products across the multiple centers. We have effectively tapped the trajectory expertise from Marshall Space Flight Center, Johnson Space Center, Glenn Research Center, and Langley Research Center.

The Trajectory Working Group is overseeing which of the complex simulation models will be used and managing the multitude of trajectory baseline assumptions. Currently, we have a long list of analysis tasks that must be completed to feed into the development of the risk estimation models. The team is primarily focused on meeting the requirements to support the ARES I-1 test flight, currently scheduled for 2009.

ARES I-1 Support

The **ARES I-1** test flight is designed to re-use many Space Shuttle solid rocket booster components while demonstrating the Constellation Program's progress in stepping into the new vision.

The flight test vehicle configuration shown to the right will consist of a four-segment solid rocket booster with a dummy fifth segment, as well as a dummy shell for the upper stage and crew exploration vehicle. The flight will demonstrate only the first



stage of flight, resulting in a sub-orbital trajectory and an Atlantic Ocean disposal of all of the components.

Other Topics Considered

Many non-trajectory topics needed the Launch Constellation Range Safety Panel's attention this past year. The baseline design for the Constellation includes re-using the Shuttle flight termination system. However, this configuration poses possible complications described below.

Flight Termination System Frequency. The National Telecommunications and Information Administration directed all ranges to shift flight termination system frequency from 416.6 megahertz to 421 megahertz region by end of 2006. In September 2006, the Administration formally granted the Space Shuttle Program a waiver to continue flight termination system support at the current frequency through the end of Shuttle program in 2010.

However, this waiver is applicable to the Space Shuttle only. Near the end of the year, it is thought that the Air Force will to be granted a waiver by the National Telecommunications and Information Administration to continue to use the 416.5 megahertz frequency through the end of 2010. Once formalized, the ARES I-1 flight will be covered by that waiver and reuse of the Shuttle flight termination system frequency will remain the plan.

Aft Segment Linear-Shaped Charge. As noted above, the ARES I-1 plan was to totally reuse the Shuttle solid rocket booster components and accept the fact that the aft segment does not have a linear-shaped charge. For the Space Shuttle, approximately 90 percent of the launch area risks are driven by the threat of an intact aft segment impacting on land and generating a large overpressure hazard.

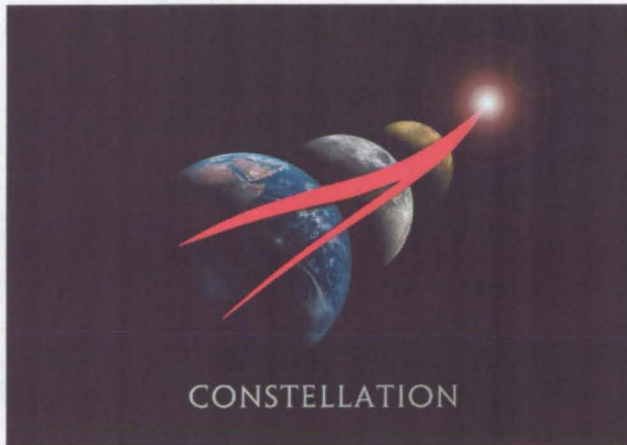
Though not fully quantified for ARES I-1, the majority of the Launch Constellation Range Safety Panel membership recommended that we amend the test flight design to include the charge extension and strive to achieve significant risk reduction. This topic has been addressed at numerous Launch Constellation Range Safety Panel meetings and was presented to the Program Manager just before the Christmas holiday.

Constellation Program Manager, Jeff Hanley, made the following decisions:

- Recommended to the flight test team that they plan to incorporate a requirement for adding flight termination functionality to the aft segment of the first stage on Ares I-1.
- Candidate design options should be included in the upcoming flight test vehicle preliminary design review; schedules adjusted as necessary.
- The Range Safety Panel will continue with planned malfunction turn analyses to be completed by late spring.

- Design options are preferred that would allow deletion of this capability (for the purpose of recovering schedule) in the event future analyses indicate a defensible technical case can be made for either meeting the NASA procedural requirement for casualty expectation (E_c) or waiving it, if the program should chose to pursue that.

It was greatly appreciated that program management was responsive to the questions and concerns raised concerning this topic while at the same time considering the project's direct critical schedule and cost impacts.



Overall, this has been a very productive and dynamic year for the Launch Constellation Range Safety Panel. Due to the high level of cooperation and professionalism exhibited by the panel members, the integration of the multiple centers and agencies has been successful. This next year promises many challenges focused on supporting the ARES I-1 test flight, as we perform a number of analyses, engage in detailed tailoring negotiations to satisfy Air Force and NASA requirements, and further establish the relationship with other projects.

Space Shuttle Range Safety Panel

The Space Shuttle Range Safety Panel has been involved in a number of activities over the past year. The panel supported three STS launches, launch area risk assessment, solid rocket booster aft segment analysis, flight termination system frequency change as well as hosting the range safety tool summit. The Columbia Debris Catalog Project and Flight Operations Version 1 software impacts to shuttle flight dynamics were also addressed.

Support of Shuttle Launches, Launch on Need, and Entry Level Safety Activities

Range Safety supported three launches in 2006 in addition to the Launch on Need rescue mission planning and entry safety activities.

STS-121. STS-121 was the first International Space Station mission to fly with a low dynamic pressure target. This change in mission profile came after the high dynamic pressure Range Safety design was complete and required some data redelivery to the 45th Space Wing so their displays could be updated for the new disposal areas. Launch day support was nominal.

STS-121 was also the first flight to have the protuberance air load ramps removed from the external tank. The Lockheed Martin Manned Space Systems assessment of this configuration with the performance enhancements certified external tank entry trajectories resulted in a violation of the external tank rupture altitude requirements (NSTS-07700 Volume X, *Space Shuttle Flight and Ground System Specification*.)

Range Safety developed new external tank entry trajectories based on current International Space Station mission profiles and presented the methodology and results to the Space Shuttle Program and the Range Safety panel. Lockheed Martin Manned Space Systems was able to use the new trajectories to clear the Volume X requirements and resolve the issue for STS-121. Subsequent flights that have the protuberance air load ramp removed from the external tank can use the new trajectories to clear the Volume X requirement.

STS-115. STS-115 products were delivered according to standard process. Due to data hits on launch day, the real time support team was required to use contingency procedures to make a determination of the potential for debris impacts on land. The anomaly and the resulting updates to Range Safety real time processes were reviewed and approved at the Range Safety panel.

STS-116. STS-116 products were delivered according to standard process. Another launch day issue required Range Safety support to use the newly implemented (post-STS-115) backup procedures to obtain the required vector for debris land impact evaluation. By using this procedure, Range Safety's launch day customers received their data within the standard delivery time.

Launch on Need Rescue Missions. Each Space Shuttle Program mission is now paired with a Launch on Need rescue mission. The Range Safety production community engineered a generic 51.6-degree Launch on Need rescue mission delivery package consisting of the ascent destruct criteria and the disposal document. The Range Safety

team presented the process and received approval from the Range Safety Panel on 8 August 2006.

The current Range Safety delivery process was tailored to reduce generation and quality assurance time while continuing to meet customer expectations. To ensure the applicability of the generic data for each future 51.6-degree Launch on Need International Space Station rescue mission, the Range Safety Team established detailed verification criteria. The verification criteria were discussed with the external customers and the flight design community.

The criteria were created to verify the applicability of generic data for each future 51.6-degree Launch on Need International Space Station rescue mission. The generic delivery package is robust and should cover all 51.6-degree Launch on Need International Space Station rescue missions through the end of the Space Shuttle Program.

Entry Range Safety Activities. The Space Shuttle Program continued support of entry range safety activities by providing two products for each of the Shuttle missions of 2006. First, the Space Shuttle Program generated expectation of casualty estimates for all potential landing opportunities for this year's missions before launch and updated these estimates daily during the last three flight days for each mission. STS-116 marked the first flight where Kennedy Space Center on-site risks were modeled with sheltering effects included.

Second, the Space Shuttle Program improved its coordination with the Federal Aviation Administration in its continuing effort to keep the Administration aware of Shuttle landing opportunities and potential debris footprints in the case of an incident during entry, so that the Federal Aviation Administration may best manage risk to the airborne public during such incidents.

Updated Inputs to Launch Area Risk Assessment

The updated launch area risk assessment effort is nearly complete. The Panel is continuing to work through the remaining open work such as space shuttle main engine failure rates and the certification of the Air Force's [Monte Carlo Launch Area Risk Assessment](#) tool. The Panel is reviewing the risk input table mission, specifically to ensure concurrence between the 45th Space Wing and NASA on the inputs and the resulting risk results. New launch area risk calculations have shown a decrease in launch area risk of two orders of magnitude. Open work includes that mentioned as well as NASA concurrence on the verification of the 45th Space Wing [Launch Area Toxic Risk Assessment](#) "3D" toxics modeling.

Solid Rocket Booster Aft Segment Analysis

Previous studies have shown that the intact solid rocket booster aft segment accounts for more than 90 percent of the overall launch area risk. The explosive yield that results from the aft segment impacting the ground is estimated using several different assumptions. One of these assumptions involves the orientation of the aft segment at the time of impact. Another assumption pertains to the amount of propellant that is burned post-destruct. The combination of these two assumptions can significantly alter

the casualty expectation values that are computed. Improving the accuracy of aft segment modeling will enhance the accuracy of the overall risk estimates.

In the spring of 2006, the 45th Space Wing presented the results of a study that analyzed solid rocket booster aft segment post-destruct burn rate and impact orientation to the Space Shuttle Range Safety Panel. The results showed that the propellant in the aft segment is expected to stop burning once destruct action is taken and the chamber pressure is released. Furthermore, the analysis results indicated that the aft segment would likely impact the ground with an angle of attack of ~70° for most failure cases after about 10 seconds mission elapsed time. The Space Shuttle Range Safety Panel is currently performing a peer review of the 45th Space Wing analysis results. Once the peer review is complete, the panel will propose a strategy for implementing the analysis results into future launch area risk assessments.

Flight Termination System Frequency Change

In March 2000, the National Telecommunications and Information Administration directed all federal test ranges to move flight termination system operations from the 406.1 - 420.0 megahertz frequency band to the 420.0 - 450.0 megahertz frequency band. Currently, the Shuttle operates on a command frequency of 416.5 megahertz.

In July 2005, the Shuttle Program Requirements Control Board decided to request a waiver of the requirement to move off of the current Shuttle frequency. In early 2006, the Space Shuttle Range Safety Panel coordinated the effort to request the waiver, and in September 2006, a National Telecommunications and Information Administration letter to NASA stated approval of the waiver to allow the Space Shuttle Program to continue flight termination system support on the current frequency until the end of the program in 2010.

The approval of the waiver was based on the assumption that development of a replacement launch vehicle will continue, and the new launch vehicle will use a flight termination system frequency other than the 406.1-420.0 MHz frequency band.

NASA Agency Range Safety Tool Summit

The Space Shuttle Program hosted the first Agency Range Safety Tool Summit in September 2006. This meeting was proposed by the Agency Range Safety Manager and the Office of Safety and Mission Assurance to minimize duplicate efforts occurring at the five NASA Centers that currently perform range safety analyses for ascent and entry. In addition to Headquarters' Office of Safety and Mission Assurance, each Center that has a range safety tool (Kennedy Space Center, Dryden Flight Research Center, Wallops Flight Facility, Jet Propulsion Laboratory, and Johnson Space Center) was represented.

The attendees discussed the capabilities of each Center's tool and decided to explore using Dryden's [joint advanced range safety system](#) as the overall integration tool for the Agency. First, Wallops' sounding rocket range safety toolset and the Space Shuttle Program's public entry risk assessment toolset will be integrated into the joint advanced range safety system as trial cases. If successful, the joint advanced range safety system will become the official overall integration tool for the Agency, ultimately hosting both the

Space Shuttle Program's ascent and entry risk assessment toolsets. The Space Shuttle Program is considering a handful of minor actions and continues to work with the Agency in development of a common toolset.

Columbia Debris Catalog Project

The [Columbia Debris Catalog Project](#) is a joint effort between the Federal Aviation Administration and NASA, made possible under Memorandum of Agreement No. FNA/10-02-01, KSC No. KCA 2055. The purpose of the project is to study the recovered Columbia debris to facilitate realistic estimates of the risk to the public. To accomplish this goal, current debris modeling assumptions must be compared and validated against real data events. The Columbia accident allows experts to use a real data event to analyze an entry breakup event and facilitate further studies on adjusting current debris risk modeling assumptions and techniques.

Approximately 90,000 debris pieces have been recovered and more are being collected on a weekly basis through the Columbia Research & Preservation Office located at Kennedy Space Center. Although the debris collected at the time of recovery in 2001 were cataloged, no piece contained sufficient characteristic data required for further debris risk modeling analysis. In 2004, this project was started and through many requirements review cycles and budgetary constraints, the USA/Change Partnering Agreement was signed on 20 July 20 2006 to begin work on collecting debris data for this project.

With a total project budget of \$145,000, work began in August 2006. The project was divided into two different phases. Because the proposed data collection process was brand new, the team decided a trial run to test the procedures would benefit any Phase II effort by increasing efficiencies in time and cost. Phase I included a two-week debris processing period with two full-time dedicated personnel. During that period, 167 debris pieces were processed. The processing team tested the requirements, acquired and tested the hardware, tested the layout of the facility, and tested and improved the procedures. The results of Phase I provided the team with sufficient throughput data and processing recommendations to make preliminary recommendations for Phase II.

The Federal Aviation Administration and NASA team will recommend data collection on the remaining debris starting with all "boxed" debris that contains approximately 50 percent of the total recovered. (Crew module debris will not be processed.) Depending on the resources available, a four person processing team could potentially catalog 16,640 pieces per year without unforeseen project interruptions. At this rate, all recovered debris could potentially be catalogued in 5.4 years.

Pilot Tone

To date Kennedy Space Center has tested the range safety system pilot tone during multiple integrated operations for STS-114, 115 and 116. Testing has occurred during integrated pad operations but not during S0007, launch count down operations, due to the difficulties related to developing launch commit criteria. Currently, the Eastern Range has come forward with the position that they will not require pilot tone for the remainder of the Shuttle program. Launch Operations is waiting for an official memo from the

Eastern Range. Once that has been received, the Panel will pursue canceling implementation of pilot tone for shuttle and closing the current program change request.

Flight Operations Version 1 Software Impacts to Shuttle Flight Dynamics

Per Program Requirements Document specifications, Wallops Flight Facility's high-speed C-band tracking data should be transmitted to Johnson Space Center uncorrected for refraction. However, during the flight of STS-114, it was discovered that the tracking data provided by the Range Operations Control Center Flight Operations Version 1 (FOV1) software was corrected for refraction. A software fix request was submitted to the FOV1, requesting that Wallops high-speed tracking data be provided to Johnson Space Center uncorrected for refraction. The implementation of the fix is not expected to occur for another 2.5 years according to the latest estimate provided at the 14 November 2006 Range Safety Panel meeting. Until the implementation is in place, Wallops high-speed data will continue to be provided to Johnson Space Center corrected for refraction, and the Mission Control Center software correction will not be used.

The FOV1 correction model is based on one modulus of refraction value for the entire year that is representative of a summer/fall atmosphere. To quantify the effects of using a single modulus of refraction on the high speed tracking data, USA Navigation performed an analysis comparing the FOV1 refraction correction to the Mission Control Center refraction correction. The results revealed that while the differences were small for the summer/fall months (June through November) when the FOV1 modulus of refraction closely resembles the Mission Control Center modulus of refraction, they were significantly larger—on the order of 1,500 feet in radial position and 15 feet/second in radial velocity—for December through May.

Operationally, the high speed tracking data will still be able to provide a state vector to correct gross onboard navigation errors. However, during the winter/spring months, the vectors will likely not be of sufficient quality to update the onboard state to correct for small planar dispersions that may have built up during powered flight (Flight rule A 4-57 F).

Launch Area Toxic Risk Assessment "3D" Certification and Implementation

The 45th Space Wing is in the process of developing a strategy for certifying and deploying Launch Area Toxic Risk Assessment "3D," a new combined debris and toxics model for Shuttle launch area risk assessment applications. The Space Shuttle Range Safety Panel will identify the appropriate personnel to assist with the evaluation and peer review of the Launch Area Toxic Risk Assessment "3D" software. The panel will coordinate the effort to implement the new model into future launch area risk assessments to achieve more accurate public risk estimates.

2006 Launches By Agency

KSC-Sponsored Launches				
Date	Vehicle	Payload or Mission	Launch Location	Responsible Organization
7/4/06	STS-121	Shuttle	KSC	NASA
9/9/06	STS-115	Shuttle	KSC	NASA
12/9/06	STS-116	Shuttle	KSC	NASA

Eastern and Western Range Launches				
Date	Vehicle	Payload or Mission	Launch Location	Responsible Organization
1/19/06	Atlas	Pluto New Horizons	CCAFS	NASA
3/22/06	Pegasus	ST-5	VAFB	NASA
4/15/06	Minotaur	COSMIC	VAFB	DoD
4/20/06	Atlas V	ASTRA IKR AV-008	CCAFS	DoD
4/28/06	Delta II	CALIPSO/CloudSat	VAFB	NASA
5/24/06	Delta II	GOES-N	CCAFS	NASA
6/21/06	Delta II	MITEX	CCAFS	DoD
6/28/06	Delta IV	NRO L-22	VAFB	DoD
7/4/06	STS 121	Shuttle	KSC	NASA
9/9/06	STS 115	Shuttle	KSC	NASA
9/25/06	Delta II	GPS 2R-15	CCAFS	DoD
10/26/06	Delta II	STEREO	CCAFS	NASA
11/4/06	Delta IV	DMSP F17	VAFB	DoD
11/17/06	Delta II	GPS	CCAFS	DoD
12/9/06	STS 116	Shuttle	KSC	NASA
12/14/06	Delta II	NRO L-21	VAFB	DoD

Wallops Flight Facility Missions

Date	Vehicle	Location	Launch Result
2/8/2006	36.193 US Terrier Black Brant	White Sands Missile Range, NM	Success
3/25/2006	30.064 DR Orion	White Sands Missile Range, NM	Success
3/25/2006	30.065 DR Orion	White Sands Missile Range, NM	Success
4/5/2006	41.068 NT Terrier MK12-Improved Orion	White Sands Missile Range, NM	Success
4/12/2006	36.203 GS Terrier Black Brant	White Sands Missile Range, NM	Success
5/17/2006	ORW-9999/1 Salisbury University SERI	WFF	Success
5/22/2006	12.058 GT Terrier M12-Improved Orion	White Sands Missile Range, NM	Success
6/2/2006	1.1 MCM Balloon (554N)	Kiruna, Sweden	Success
6/5/2006	41.073 DR Terrier Improved Orion	White Sands Missile Range, NM	Success
6/7/2006	41.071 DR Improved Orion	PMRF, Kauai, HI	Success
6/8/2006	41.074 DR Terrier Improved Orion	PMRF, Kauai, HI	Success
6/8/2006	NRW-4527 Super Loki Dart	WFF	Success
6/8/2006	NRW-4498 Improved Orion SubSem	WFF	Success
6/8/2006	30.072 NO Orion	WFF	Success
6/23/2006	41.072 DR Terrier Improved Orion	PMRF, Kauai, HI	Success
7/1/2006	41.056 UO Terrier Orion	White Sands Missile Range, NM	Success
7/2/2006	42.002 DP Terrier Lynx	PMRF, Kauai, HI	Success
7/3/2006	42.003 DP Terrier Lynx	PMRF, Kauai, HI	Success
7/8/2006	1.1 MCM Balloon (556N)	Kiruna, Sweden	Success
7/12/2006	0.8 MCM Balloon (1592P)	Palestine, TX	Success
7/19/2006	NRW-4553 NFB 1/2 Scale Patriot	WFF	Success
7/21/2006	30.066 DR Improved Orion	White Sands Missile Range, NM	Success
7/21/2006	30.067 DR Improved Orion	White Sands Missile Range, NM	Success
8/16/2006	DRW-4536 BQM-34	Wallops Island	Success
8/21/2006	36.238 DR Terrier Black Brant	White Sands Missile Range, NM	Success
8/25/2006	36.237 DR Terrier Black Brant	White Sands Missile Range, NM	Success
8/26/2006	0.8 MCM Balloon (557NT)	Ft. Sumner, NM	Success
9/4/2006	0.3 MCM Balloon (558N)	Ft. Sumner, NM	Success
9/18/2006	0.3 MCM Balloon (559N)	Ft. Sumner, NM	Success
9/23/2006	NRW-4436 Black Brant XI	WFF	Success
9/25/2006	1.1 MCM Balloon (560N)	Ft. Sumner, NM	Success
9/30/2006	0.8 MCM Balloon (561NT)	Ft. Sumner, NM	Success
10/28/2006	36.233 UE Terrier Black Brant	White Sands Missile Range, NM	Success
11/7/2006	36.233 UE Terrier Black Brant	White Sands Missile Range, NM	Success
11/21/2006	36.224 UH Terrier Black Brant	White Sands Missile Range, NM	Success

Dryden Flight Research Center Missions

Date	Project Name	Mission	Flight Duration (Hours)	Location	Mission Result
6/28/2006	Autonomous Soaring UAV	2 flights	0.5/flight	Edwards AFB	Success
07/26/2006	Altair	Pod Checkout Flight	7.5	Edwards AFB	Success
8/15/2006	Altair	Fire Mission Sensor Checkout Flight	1.8	Gray Butte Airspace, Palmdale, CA	Success
8/16/2006	Altair	Fire Mission Sensor Checkout Flight	8.6	Edwards AFB	Success
10/11/2006-10/12/2006	Altair	Fire Mission Sensor Checkout Flight	21	Edwards AFB and R-2508	Success
10/19/2006-10/20/2006	Altair	Fire Mission Science Flight	23	Edwards AFB and R-2508	Success
10/24/2006-10/25/2006	Altair	Fire Mission Science Flight over Yosemite National Park	21.6	Edwards AFB, R-2508, National Airspace System	Success
10/28/2006-10/29/2006	Altair	Science Flight over Esperanza Fire	16.7	Edwards AFB, R-2508, National Airspace System	Success

SUMMARY

Throughout 2006, Range Safety was involved in a number of exciting and challenging activities and events, from developing, implementing, and supporting Range Safety policies and procedures—such as the Space Shuttle Launch and Landing Plans, the Range Safety Variance Process, and the Expendable Launch Vehicle Safety Program procedures—to evaluating new technologies. Range Safety training development is almost complete with the last course scheduled to go on line in mid-2007. Range Safety representatives took part in a number of panels and councils, including the newly formed Launch Constellation Range Safety Panel, the Range Commanders Council and its subgroups, the Space Shuttle Range Safety Panel, and the unmanned aircraft systems working group.

Space based range safety demonstration and certification (formerly STARS) and the autonomous flight safety system were successfully tested. The enhanced flight termination system will be tested in early 2007 and the joint advanced range safety system mission analysis software tool is nearing operational status. New technologies being evaluated included a processor for real-time compensation in long range imaging, automated range surveillance using radio interferometry, and a space based range command and telemetry processor. Next year holds great promise as we continue ensuring safety while pursuing our quest beyond the Moon to Mars.

We hope you have enjoyed our new web-based format. Anyone having questions or wishing to have an article included in the 2007 Range Safety Annual Report should contact Alan Dumont, the NASA Range Safety Program Manager located at the Kennedy Space Center, or Michael Dook at NASA Headquarters.

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